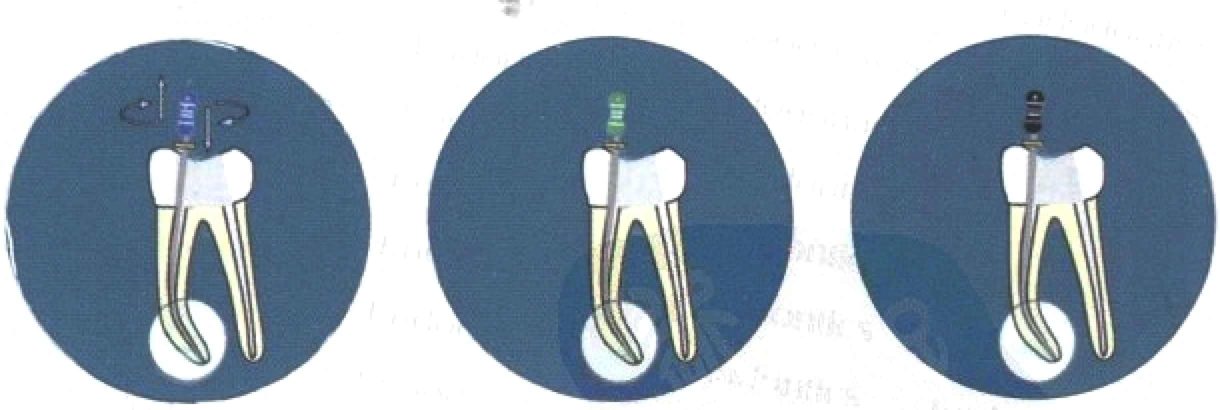
Endodontics Manual for the General Dentist

口腔临床指导丛书·中英文对照

根管治疗临床指南

著者／Martin Trope
Gilberto J. Debelian

译者／刘荣森　李颖超　林　菲



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9 787509 113943 >

销售分类 口腔医学

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林 菲 北京协和医院口腔科

人民軍醫出版社
PEOPLE'S MILITARY MEDICAL PRESS
北京

图书在版编目（CIP）数据

根管治疗临床指南／（美）特罗普（Trope,M.），
(巴西)德比利安（Debelian,G.J.）著；刘荣森，李颖超，林菲译.—北京：人民军医出版社，2008.1
书名原文：Endodontics Manual for the General Dentist
ISBN 978-7-5091-1394-3
Ⅰ.根… Ⅱ.①特…②德…③刘…④李…⑤林… Ⅲ.牙髓病-根管治疗-指南 Ⅳ.R781.305-62
中国版本图书馆CIP数据核字（2007）第177698号

Endodontics Manual for the General Dentist,by Martin Trope and Gilberto Debelian,ISBN1-85097-089-0,由国际精萃出版集团(International Quintessence Publishing Group)提供中文版权，授权人民军医出版社出版并在全球发行该书中文版。

版权登记号：图字—军—2007—021 号

策划编辑:杨 淮 **文字编辑**:马若华 **责任审读**:黄栩兵
出 版 人:齐学进
出版发行:人民军医出版社 **经销**:新华书店
通讯地址:北京市100036信箱188分箱 **邮编**:100036
质量反馈电话:（010）51927270；（010）51927283
邮购电话:（010）51927252
策划编辑电话:(010)51927300-8027
网址:www.pmmp.com.cn

印刷:北京印刷一厂 **装订**:春园装订厂
开本:889mm×1194mm 1/32
印张:5 **字数**:140千字
版、印次:2008年1月 第1版 第1次印刷
印数:0001～2700
定价:50.00元

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内容提要

本书是一本指导根管治疗的实用手册，主要内容包括牙髓病学导言，可逆性牙髓炎、不可逆性牙髓炎和坏死性牙髓炎的诊断，根管治疗的定义、临床操作，以及牙髓治疗的结果和预后等。

本书内容精练，结构合理，大量的精美插图对阅读理解、指导操作将发挥事半功倍的效果，特别适合口腔专科医师、口腔全科医师及研究生等阅读参考。

前　言

根管治疗需要熟练而高超的操作技能。然而，诊断错误、对相关生物学基础缺乏深刻的理解，再精湛的操作技术也不能取得成功，反而会把精力消耗在复杂的操作或不恰当的治疗过程中。如果诊断正确，加上合理选用新材料、采用新技术则可获得极高的成功率，并能保护健康的根尖周组织。希望读者阅读完本手册后将会发现牙髓病治疗既简单易行，又有把握取得治疗成功。

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1 牙髓病学导言

在开展牙髓病治疗之前，明确理解牙髓病学的临床定义对医师来说极其重要。作为医疗卫生专业的一部分，不同的口腔专业关注不同特定疾病。对于牙髓病学，关注的疾病是根尖周炎，即牙齿根尖区牙周附着的炎症。在极少的病例中，源自根管感染的牙周炎的病变部位可能不位于根尖区——被称为根周牙周炎。根尖周炎可表现为来自根尖牙周膜的疼痛，或更为常见的X线片透射影像（无痛）（图1–1）。其组织学表现类似肉芽肿或囊肿（图1–2）。

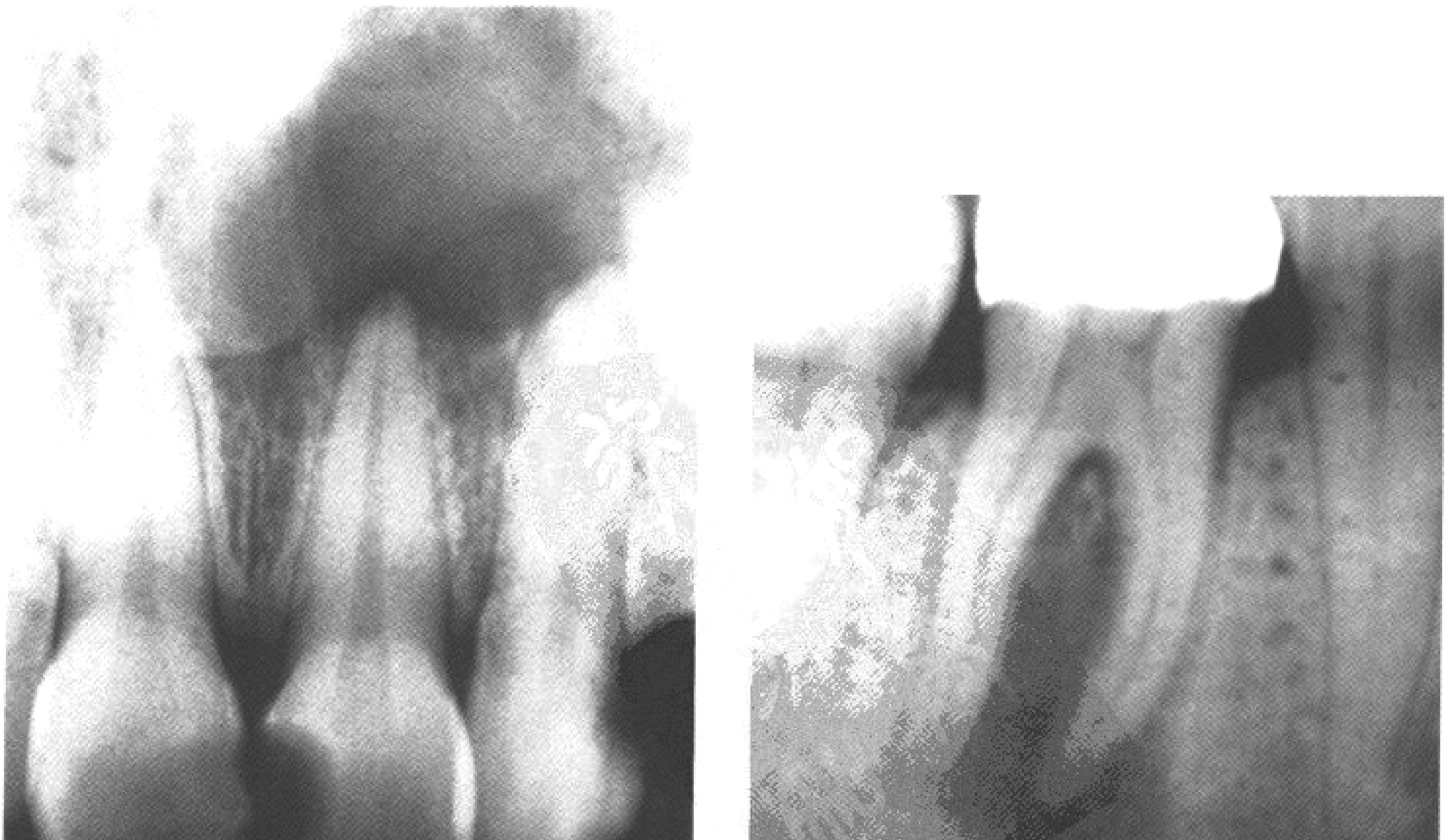


图 1–1　（a）患慢性根尖周炎的上颌中切牙表现为透射阴影；（b）下颌磨牙，显示典型的根尖周炎的 X 线片透射影像

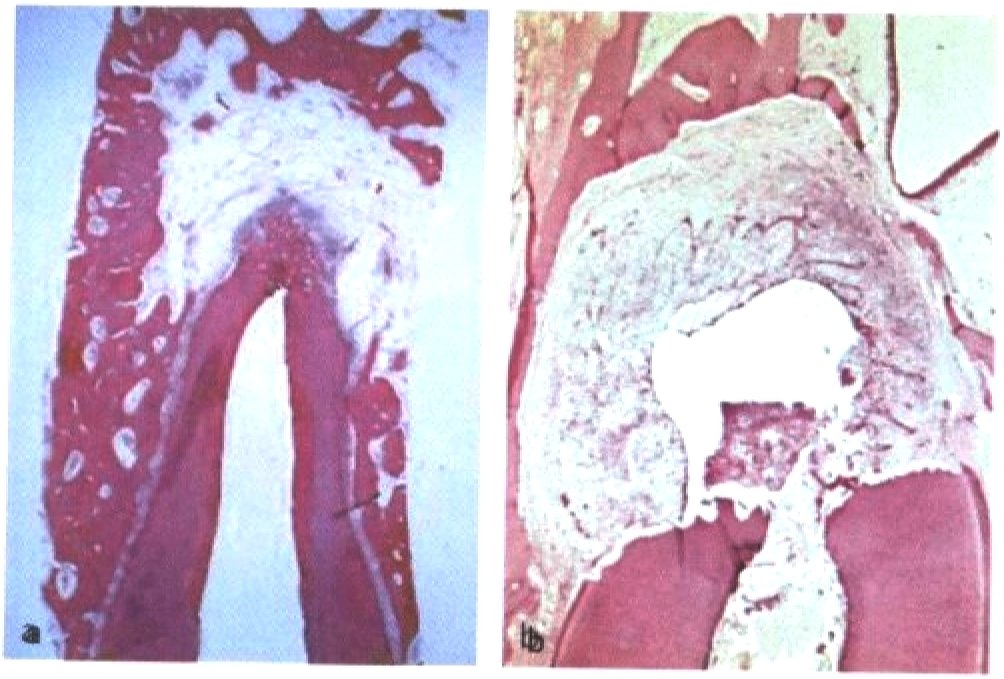


图1–2 组织学上，根尖周病损有时类似（a）肉芽肿，或（b）囊肿

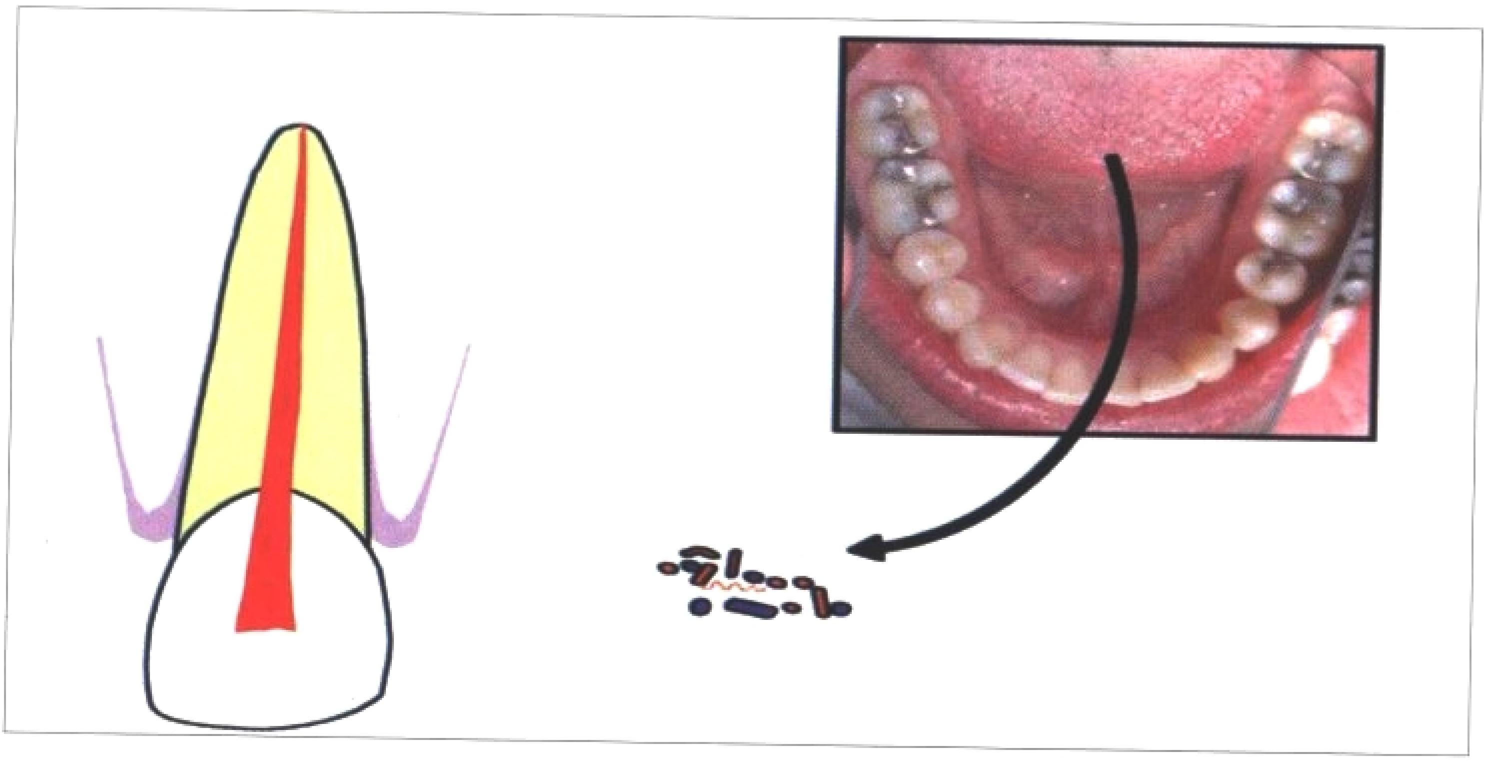


图1–3a 口腔微生物对牙髓的健康构成持续性威胁。除活髓组织的免疫应答之外，牙釉质和牙本质构成抵御细菌入侵的物理屏障，可防止根尖周炎的发生

发生根尖周炎时，大部分髓腔必然会受到感染（图1–3a～c）。发生在根管系统中的炎症一经形成，牙髓一定会发生坏死。因此，从临床上来看，牙齿发生根管感染导致的根尖周炎时，其牙髓活力测试应为死髓。

如果根尖周炎的特征是牙髓感染和坏死，那么就存在一个问题——活髓组织在牙髓病中的作用是什么？如果坏死和感染确实

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是根尖周炎的必要因素，那么大部分牙髓仍然存活时就不应被诊断成根管来源的根尖周炎。因此，保持牙髓的活力或趁其仍有活力时去除牙髓就能够避免发生根尖周炎。

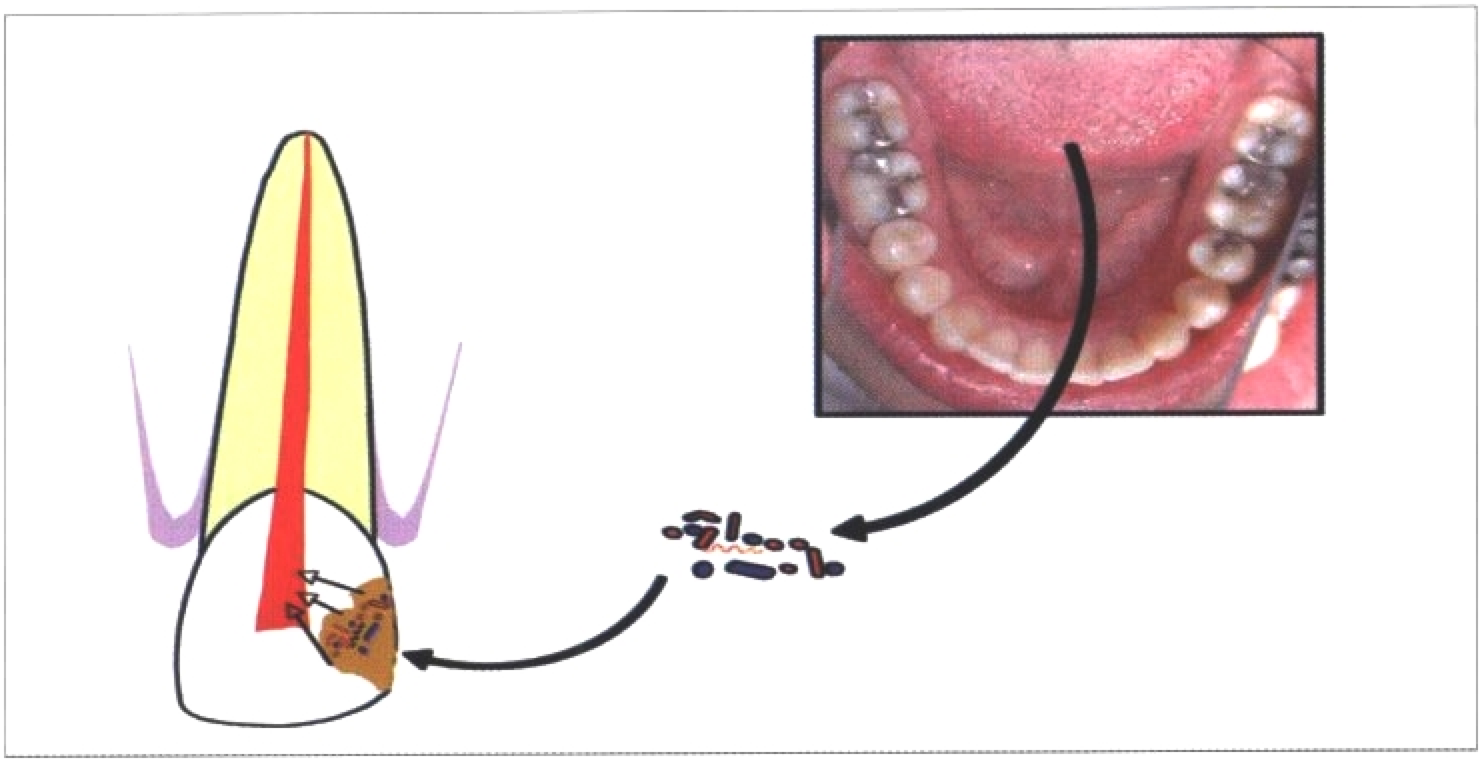


图 1－3b 如果微生物能够穿过牙釉质和牙本质，牙髓组织就会产生炎症反应（可逆性或不可逆性）。如果牙髓直接暴露于微生物感染，就会产生被炎症区环绕的坏死区，随着时间的推移，坏死区逐渐扩大，促使炎症区向根尖扩展

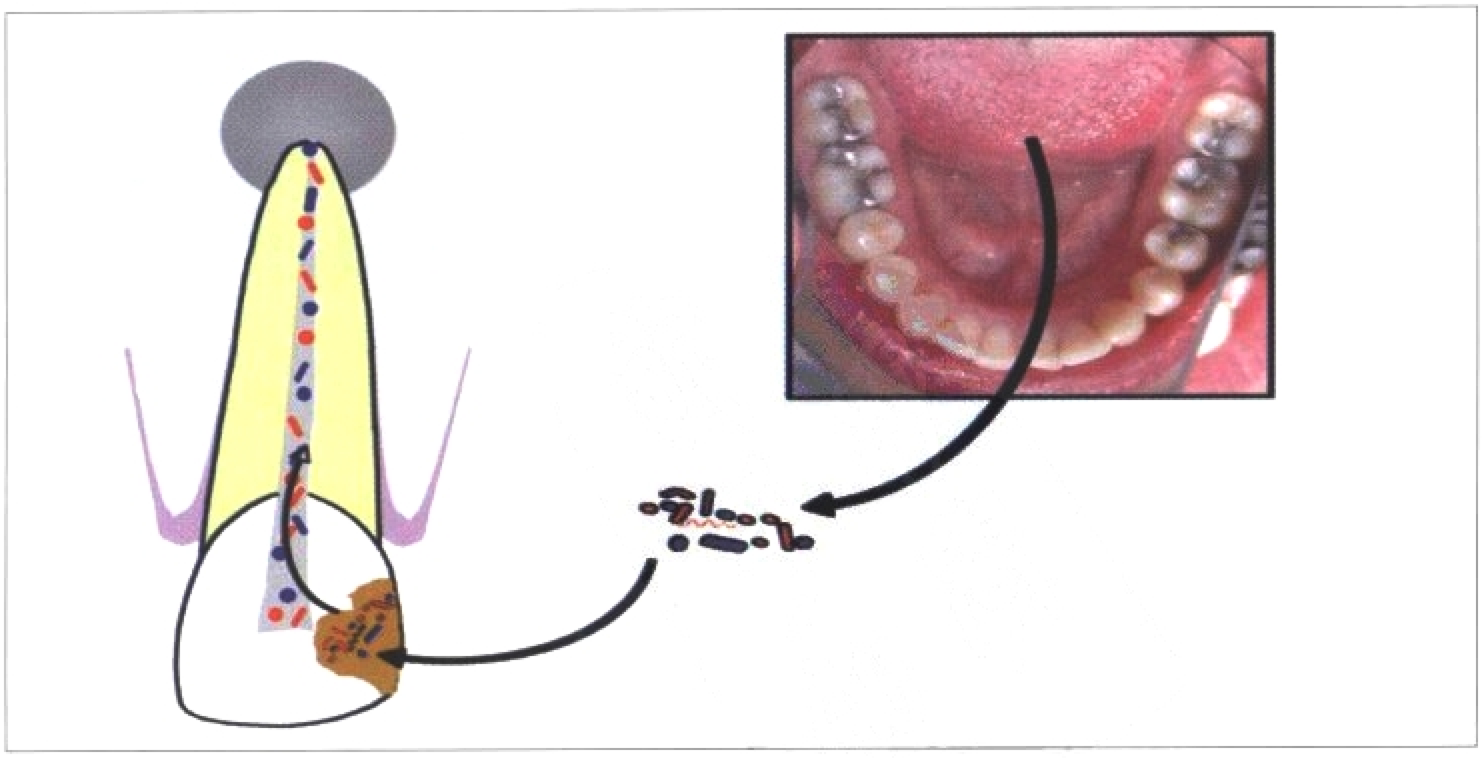


图 1－3c　当大部分牙髓坏死后，炎症超出根尖孔，形成根尖周炎

这样看来，根管治疗的目的就是预防或消除根尖周炎。通过活髓治疗可以预防根尖周炎，而对根管系统进行消毒处理则可消除根尖周炎。

对活髓牙和牙髓已感染坏死的牙齿应采取不同的治疗方针，才能取得相同的成功率，这一点将在下一章中论述。

活髓治疗术

活髓治疗可分为2类：可逆性牙髓炎的治疗和不可逆性牙髓炎的治疗。这些诊断性名词意味着：如果对一组符合可逆性牙髓炎病史、体征和症状的牙齿进行标准的牙体治疗，可预期大多数的牙髓能够恢复健康状态。由于健康的牙髓不会导致牙髓来源的根尖周炎，所以，将炎性牙髓转变成健康牙髓的治疗是最好的牙髓治疗（图1—4）。

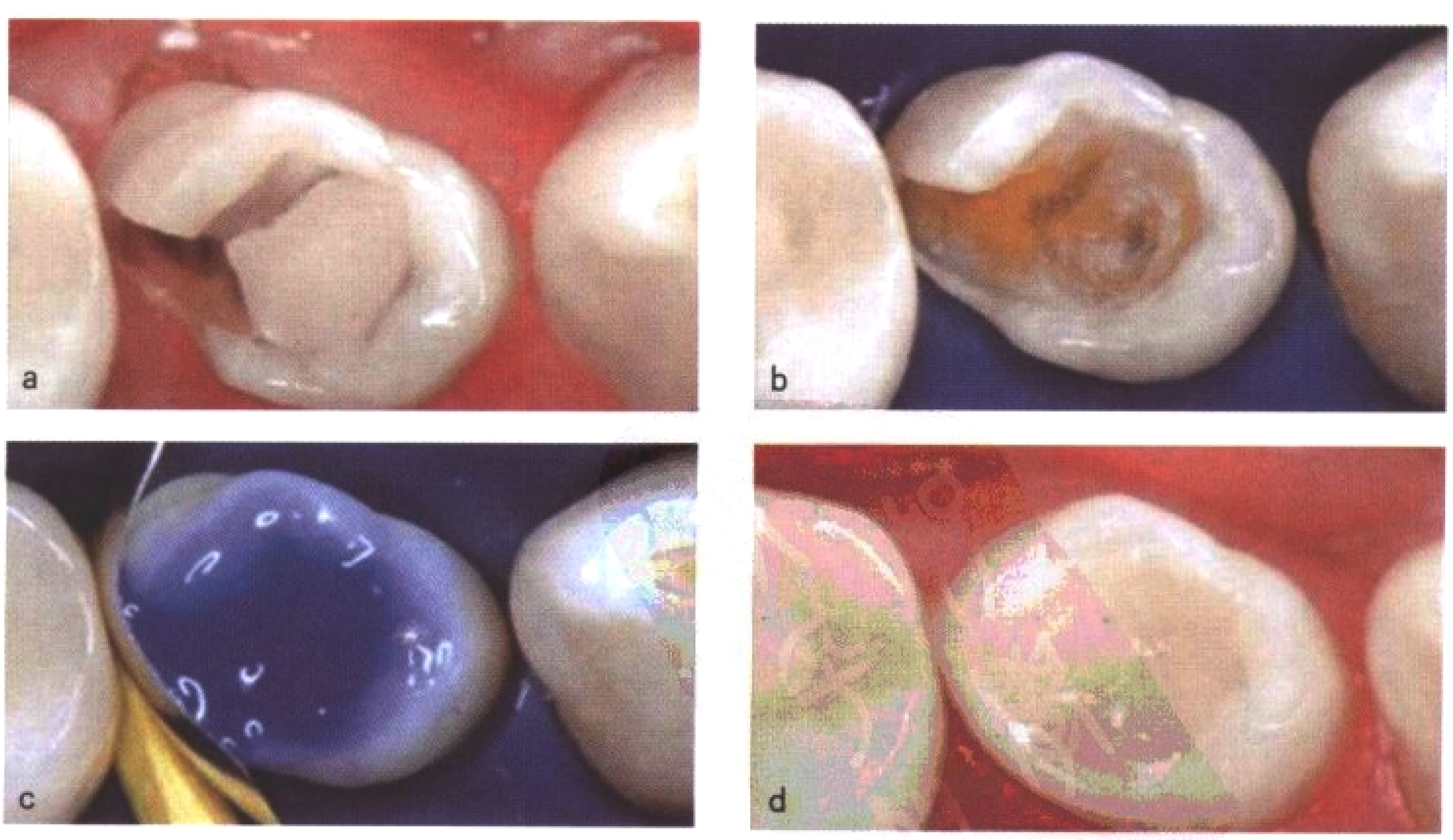


图1—4　活髓治疗。(a) 牙体修复失败，出现继发龋，诊断为可逆性牙髓炎；(b) 去除龋损；(c) 酸蚀预备面；(d) 粘结树脂材料修复

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与之相反，如果对一组符合不可逆性牙髓炎诊断特征的牙齿也进行以上的治疗，那么，多数的牙髓就会坏死、感染并发展成根尖周炎。因而，对于这种病例最好的预防治疗是无菌去除全部牙髓（牙髓切除术）并充填根管及冠方通路（图1–5和图1–6）。

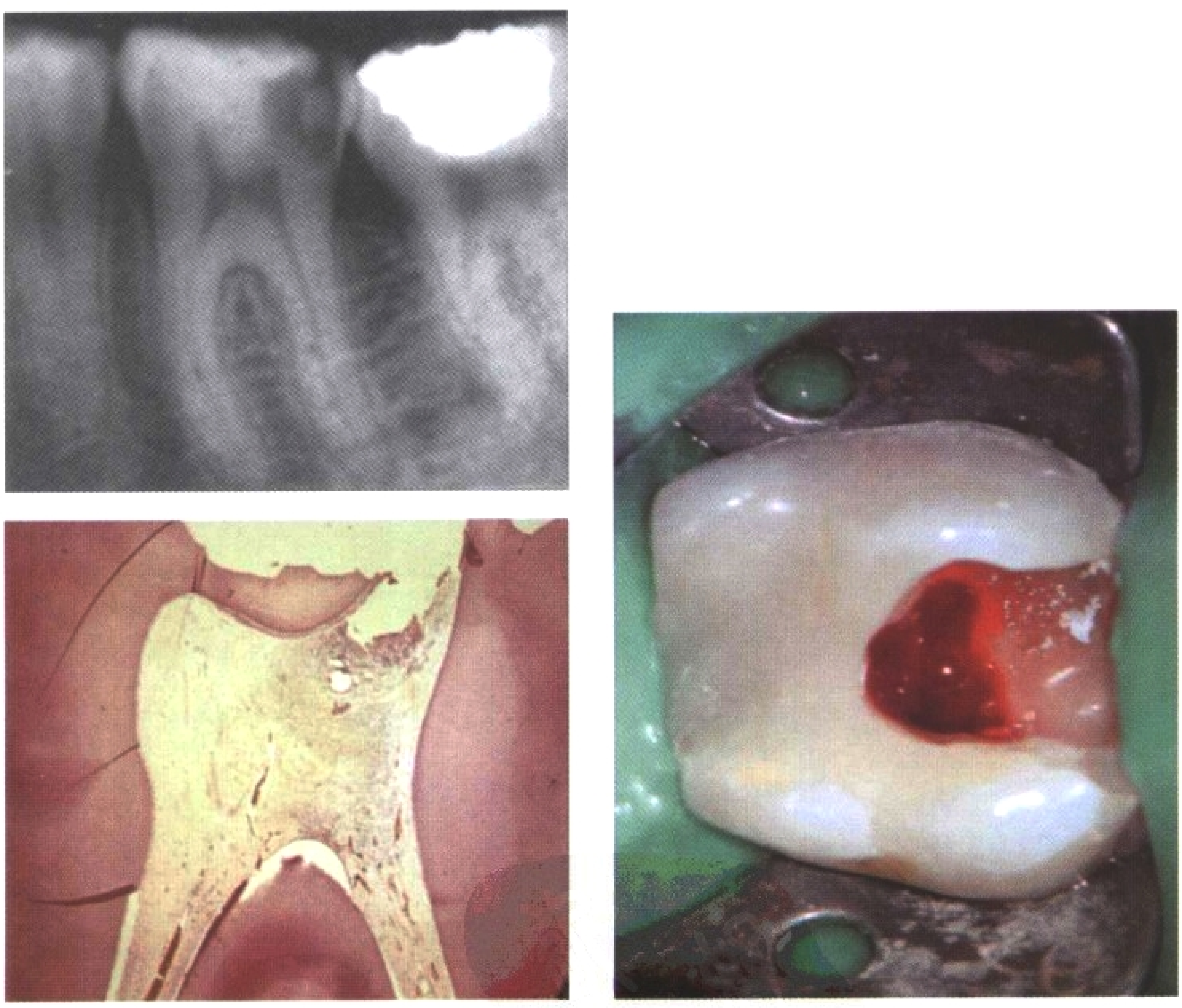


图1–5　龋损暴露牙髓，并有不可逆性牙髓炎的症状（见第2章）。为预防根尖周炎，牙髓切除术是最可靠的治疗方法

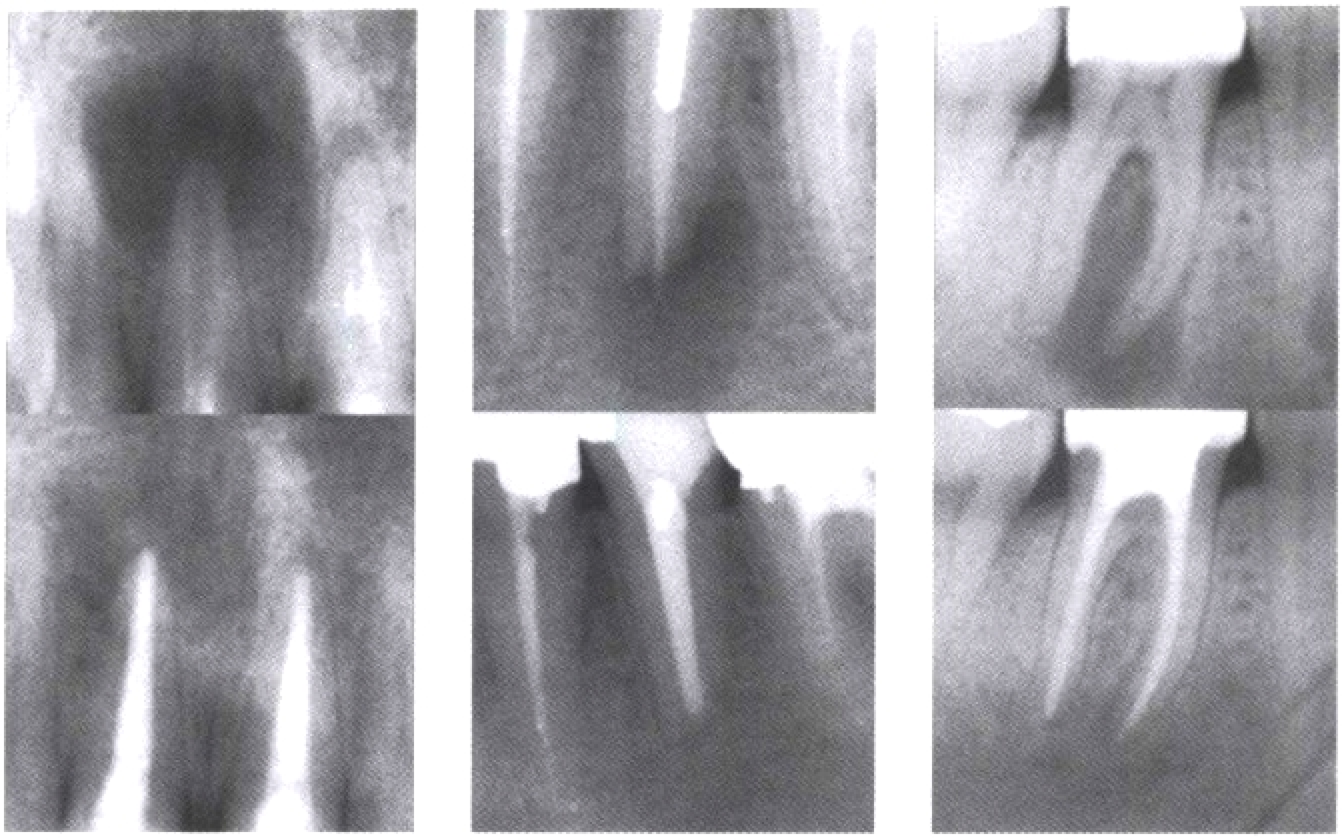


图 1－6　治疗前（上）和治疗后的 X 线片，显示根尖周炎的愈合状况

坏死髓治疗术

由于细菌是造成根尖周炎的原因，清除细菌即可消除病变。如果将细菌量降低到可以忽略的水平，并尽快将全部腔隙（根管腔和开髓洞腔）完全充填封闭，成功治疗根尖周炎的概率将会非常高。

推荐读物

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2 可逆性牙髓炎，不可逆性牙髓炎和坏死性牙髓炎的诊断

如第 1 章中所述，对于诊断为可逆性牙髓炎，不可逆性牙髓炎和坏死性牙髓炎的牙齿，其治疗方法是不同的。因而，明了对这三种临床状况进行鉴别诊断的诊断特点将非常重要。

虽然患者经受的疼痛特征常可用来进行鉴别诊断，但值得注意的是，无论患牙髓炎还是根尖周炎，都不一定出现疼痛（图 2–1）。因此，临床检查发现和对牙髓反应形式的把握是得出正确诊断的基础。

应该承认的是，目前所用的牙科诊断工具还是非常粗糙和不准确的。有鉴于此，与其依赖一种自己善用的特定测试，不如通过多项检测以获得尽可能多的临床信息。

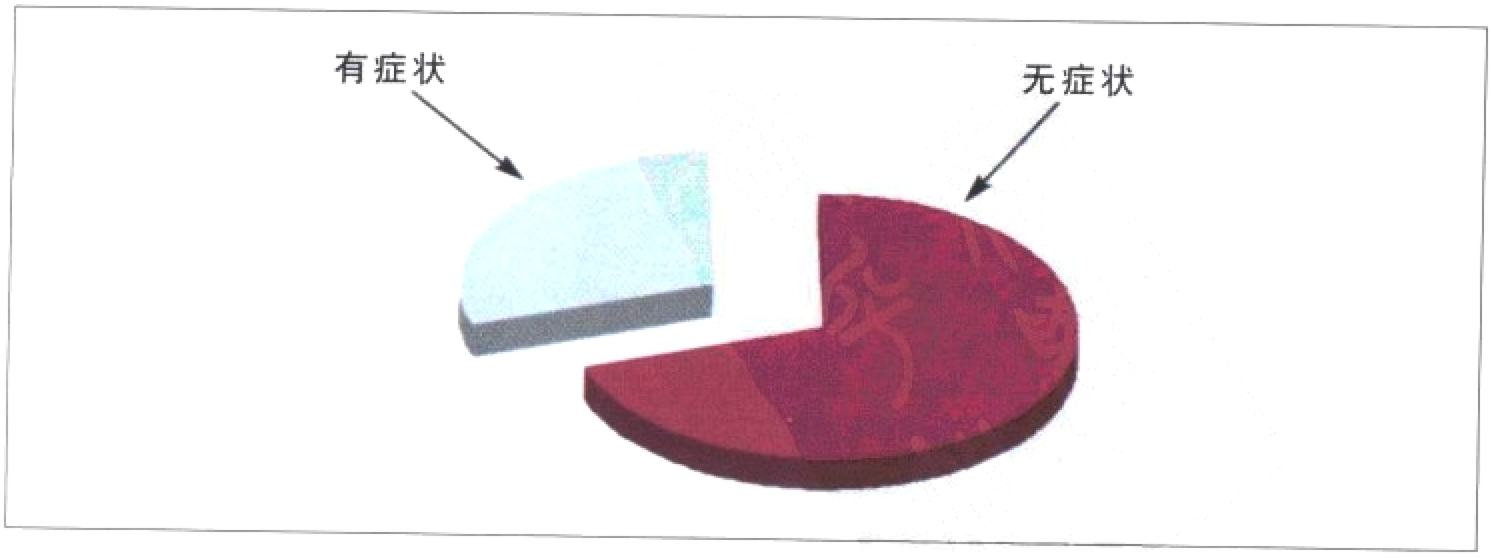


图 2–1　牙髓炎和根尖周炎患者中有症状和无症状的比例

最后，医生必须尽可能做出有根据的推测。但是，即使是最谨慎、最有经验的医生也会误诊。因而，随诊患者和验证诊断是必须的。没有疼痛并不是临床治疗成功的最终表现，因为在许多病例中无痛只是暂时的。因此，需要对临床症状、诊断测试和临床检查结果进行仔细分析后再作出诊断。

症状学

主诉

要求患者说出导致他来诊所就诊的原因，这会为判断牙髓的状态、牙髓仍有活力或已坏死、炎症的可逆或不可逆等提供重要线索（图 2–2）。

相关症状	
可逆性牙髓炎	不可逆性牙髓炎
无痛	无痛
锐痛	深部钝跳痛
	遇冷热液体疼痛
	热刺激引起疼痛，遇冷缓解
	咬合痛

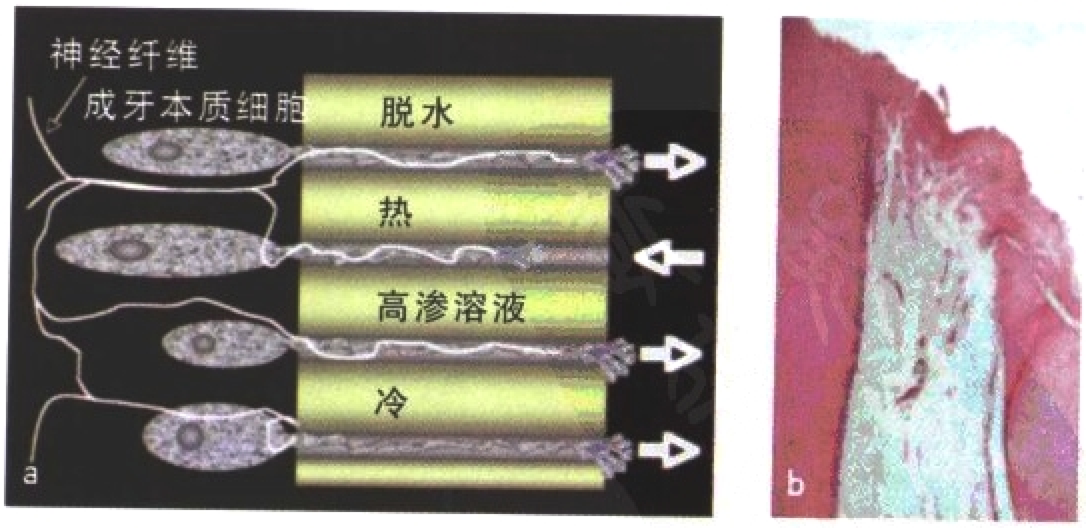


图 2–2　可逆性牙髓炎和不可逆性牙髓炎的主要区别在于各自造成的疼痛性质不同。(a) 牙髓外周的 A–δ 纤维导致受刺激时锐痛的感觉；(b) 牙髓中央的 C 纤维引发剧烈的钝跳痛

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活髓：（a）无症状，或（b）接触冷热液体或盐糖类物质时疼痛。

坏死牙髓：（a）无症状，或（b）受压，咬合时疼痛，持续疼痛。

无温度刺激痛。有疼痛，但不一定很剧烈。注意：如果现有症状证实牙齿既有活髓又有死髓，应怀疑牙尖或牙齿折裂。

可逆性牙髓炎：无症状，或接触冷热液体或盐糖类物质时疼痛（通常较轻）。疼痛较尖锐，去除冷、热、盐、糖等刺激后疼痛消失。疼痛一般不是很严重。

不可逆性牙髓炎：无症状，或接触冷或（尤其是）热液体或盐糖类物质时疼痛，疼痛的性质为剧烈的、暴发性的、深部的、令人痛苦的、搏动性和气胀性的。

鉴别诊断特征

可逆性牙髓炎：轻中度疼痛。病痛的性质为锐痛。

不可逆性牙髓炎：剧痛。病痛的性质是深部钝性的、暴发性的、令人痛苦的和气胀性的疼痛。

主诉史：医师必须逐一找出患者遗漏的导致其就诊的原因。

牙髓坏死：提问患者，以确认疼痛与温度刺激无关，但在咬合、受压时出现。

可逆性牙髓炎与不可逆性牙髓炎：为了鉴别可逆性牙髓炎与不可逆性牙髓炎，应对患者进行细致的询问，直至发现两者的关键不同。

疼痛的性质

可逆性牙髓炎和不可逆性牙髓炎的关键区别在于疼痛的性质（如果存在疼痛）。外周的A－δ纤维受到刺激时很可能是可逆性牙髓炎，刺激这种神经会导致尖锐的刀割样疼痛。然而，如果位

于中央的C纤维受到刺激，所引发疼痛的性质多半会被描述为严重的、深部的、钝性的、令人苦恼的和迁延性的。出现后一类疼痛提示患有不可逆性牙髓炎。

疼痛史

患可逆性牙髓炎时，患者一般主诉患牙原来从未疼痛过。如果患者诉说患牙原来曾出现过疼痛，而且疼痛为自发性的，夜间被痛醒，或热刺激引起的疼痛遇冷水能够缓解等，即可明确诊断为不可逆性牙髓炎。另外，出现难以准确定位的剧烈疼痛（牵涉痛）意味着不可逆性牙髓炎。

在这一阶段，医生必须非常清楚怎样对问题牙进行诊断，剩下的诊断性检查用来确定哪个牙齿符合这一诊断。

诊断性测试

如前所述，用来诊断牙髓炎和牙髓坏死的测试是主观的和相当粗糙的，因而，测试可疑牙时，必须将测得的结果与健康牙的测试结果进行对比。测试必须反复进行多次以确定患者的反应基本一致。一般情况下，诊断性测试仅能鉴别出活髓还是死髓，目前的检测手段还难以对可逆性牙髓炎和不可逆性牙髓炎进行鉴别。

温度测试

温度测试依赖于牙本质小管中的液体流动。牙齿遇冷或遇热后，牙本质小管中的液体运动就会刺激包括A－δ纤维在内的外周牙髓组织，造成尖锐性“疼痛”。如果牙髓的炎症非常严重，那么，牙髓组织的膨胀（热刺激）或收缩（冷刺激）就可能刺激到位于牙髓中央的C纤维。

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冷测试

应该用二氯二氟甲烷（–40℃）或干冰（–70℃），这些检测剂优于氯乙烷（–4℃）或冰块，后者接触牙面后容易融化扩散到邻牙。测试前牙时，冷源应置于切1/3处。，后牙则应置于其近中颊尖的切向部分。这些部位一般对应着髓角，是牙髓中神经分布最集中的地方（图2–3）。对同一牙齿进行再测试前，应等待一段时间使牙髓恢复正常。

如果测试结果持续阴性，97%的牙齿至少已局部坏死，需要进行根管治疗。测试阳性说明牙齿还有活力。除非阳性反应明确来自C纤维（深部的、钝性的、令人苦恼的和暴发性的疼痛），对冷刺激产生阳性反应本身不能确定牙髓的炎症是可逆的还是不可逆的。

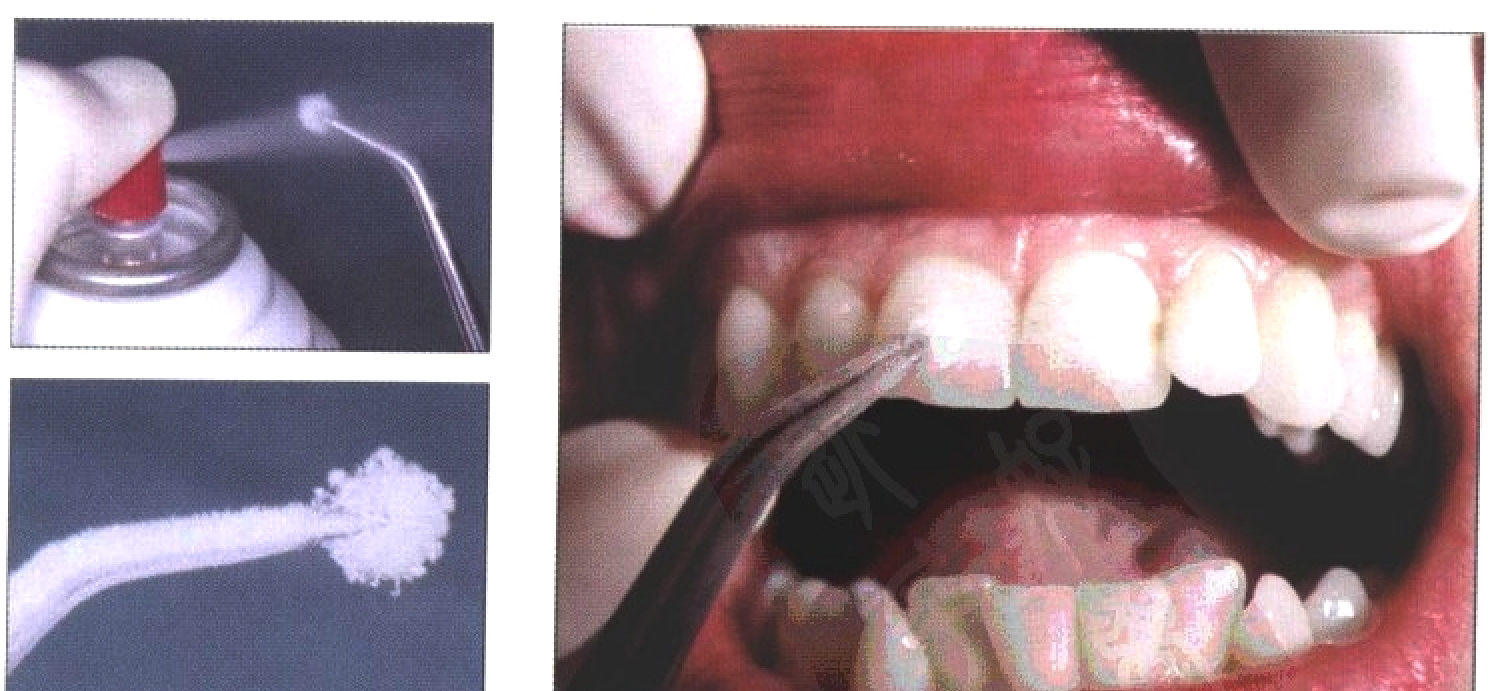


图2–3　进行冷测试时最有效的检测剂是二氯二氟甲烷（–40℃，见图）或干冰（–70℃），测试时应将其直接置于牙齿唇颊侧的切1/3。也可用氯乙烷（–4℃）或冰块进行测试

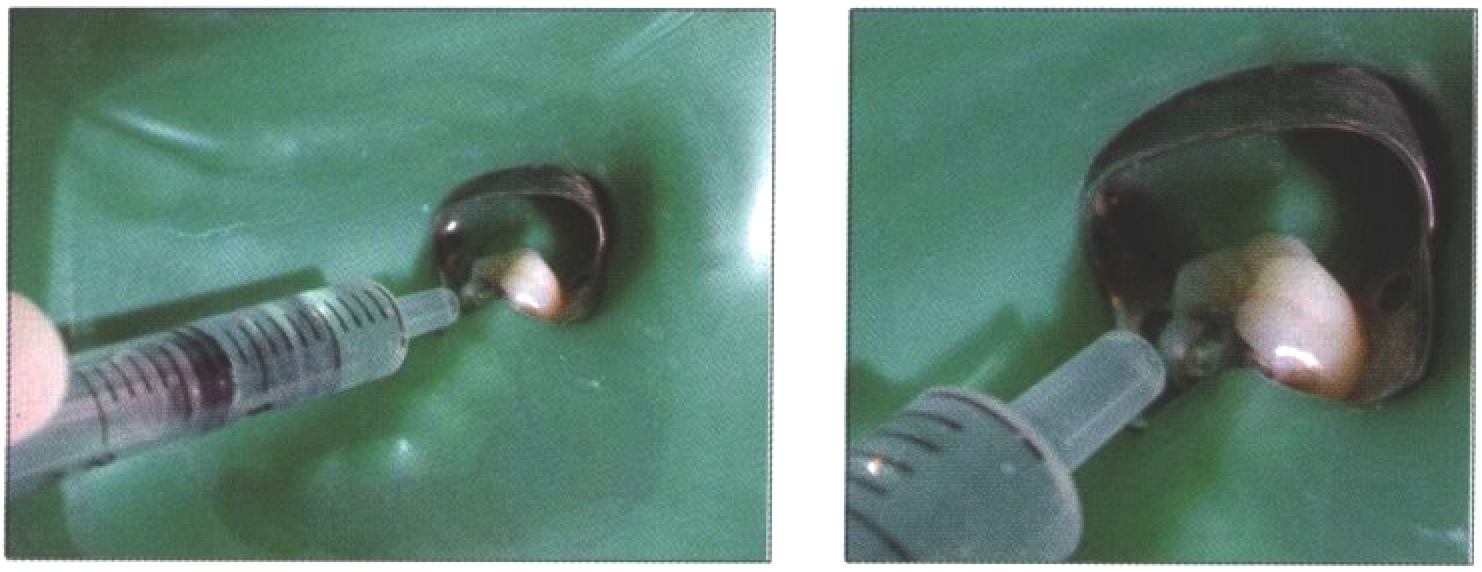


图 2－4 进行热测试时，应用橡皮障将问题牙隔离，用注射器将热水轻轻喷注到牙齿上，直至覆盖全部牙面。此检测可反复进行多次，每次测试时应换用新的热水

热测试

目前尚无非常有效的热测试手段，最好的方法是热水浸浴。首先确定患牙所在的区限，然后患者仰卧位设置橡皮障，测试从最后方的牙齿开始。用注射器将热水轻轻喷注到牙齿上，直至覆盖全部牙面（图 2–4）。如果测试未能激发出患者的症状，就要将橡皮障移至前一个牙齿上重新开始测试，每次测试时应换用新的热水。重复这一过程直至引发出疼痛。和冷测试一样，反复检测阴性说明需要对牙齿进行根管治疗。不过，阳性反应本身不能确定牙髓的炎症是可逆的还是不可逆的。

电测试

电测试（EPT）通过直接刺激牙髓中的神经纤维来探知牙髓的活性。这种方法在测试老年人牙齿和因牙本质小管硬化和闭合导致小管液流动受限的牙齿时尤其有效。同样，前牙的切 1/3 和后牙近中颊尖的切 1/3 也是 EPT 最佳的测试部位（图 2–5）。和冷、

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图 2－5　进行电测试时，应使电极接触受测牙的切缘，为保证接触良好，局部可涂敷牙膏

热测试一样，阴性反应提示牙髓坏死，而阳性反应只提示牙髓仍有活力。

备洞测试

如果牙齿上的修复物妨碍热或电刺激的传导，上述的诊断性测试就无法进行。在这种情况下，惟一的选择就是在修复体上开窗，使测试得以实施。由于向冠内和牙本质内钻洞会导致小管液的流动，如果不实施麻醉，这一过程本身就能够有效地测试牙髓的活力状况，因此，其通常被称为备洞测试。我们认为，备洞测试只应用作为最后的选择，而且只在预期牙髓正常或可逆性炎症的情况下使用。操作时喷水必须十分充分，用轻触手法钻洞。

叩诊和扪诊

叩诊和扪诊用来评估是否存在根周炎症。由于绝大多数的死髓牙中都存在根周炎症，在患牙对温度测试或 EPT 无反应的情况下，叩诊和扪诊测试阳性能够用来辅助指示根尖周炎。另外，随

着牙髓的坏死，发生不可逆性炎症的牙髓能够迅速导致根周组织的炎症，通过根分歧部位的根管或位于牙根高处的侧支根管传播的炎症尤其迅速。如果活髓牙存在根周炎症，即可认为根髓组织有炎症，而且牙髓炎症不可能逆转。所以，活髓牙的叩诊和扪诊测试阳性（过敏）提示不可逆性牙髓炎。

叩诊时应用口镜的后端或其他金属器械叩击患牙，注意使尽可能多的根面牙周韧带受到"刺激"。由于在多数的病例中炎症位于根尖部位，应沿牙齿的长轴叩击受测牙（图2–6）。另外，也可以在多方向上叩测可疑牙，使测试覆盖尽可能多的根面。虽然叩诊和扪诊测试过敏意味着牙周韧带存在炎症，但测试结果正常并不能说明没有炎症，测试过程中有可能遗漏某些炎症部位。

虽然扪诊也可以测试牙周韧带的炎症，但用途较叩诊局限，实际上只适用于测试根尖区的唇颊侧（图2–6），因此，这项检测会遗漏根面的很多部位。扪诊阳性可能意味着牙髓发生坏死性炎症，这是因为只有非常明显的的根尖周区炎症才会造成透过颊侧



图2–6 （a） 叩诊是一种简单而有用的方法，测试时用口镜等器械的手柄垂直向叩击牙齿；（b）扪诊用于确定检测部位组织的触痛、肿胀、波动和捻发感

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根尖骨皮质的扪压痛。不过在极少的病例中，活髓患牙的扣诊阳性有可能指示不可逆性牙髓炎。

X 线检查结果

把这一部分内容放在章节的后面并非偶然。X 线片是一种二维的灰度图像，其能够提供的诊断信息非常有限，认识这一点十分重要。医生常常过于依赖 X 线片做出全部诊断。

发生牙髓坏死和根尖周炎的患牙可能显示根尖周透射区，而可逆性牙髓炎则不会出现根尖周透射区。发生不可逆性牙髓炎的牙齿一般不会（但在极少情况下可能）显示根尖周硬骨板增厚（图 2–7）。

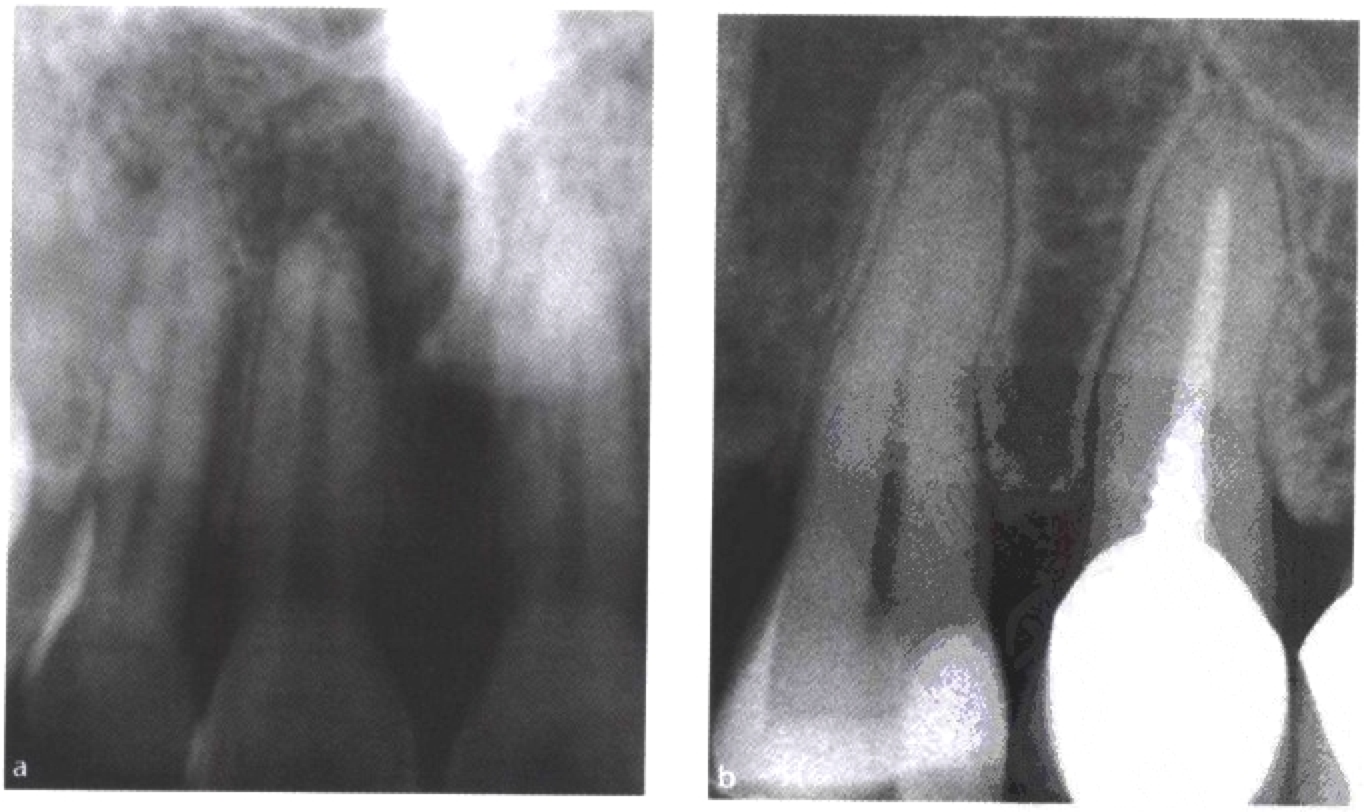


图 2–7　患慢性根尖周炎的死髓牙（a）以及患可逆性牙髓炎活髓牙的典型 X 线片表现（b）

临床检查结果

对患者的症状和诊断性测试结果进行评估后，医师应该能够做出诊断并确定患牙。在多数情况下，临床发现可以帮助证实诊断，但有时却会促使医师改变诊断。

发育完成牙的龋损露髓

目前，对于发生在发育完成牙中的龋损露髓尚无效果明确的活髓治疗方法。鉴于治疗的目的在于预防根尖周炎，对于这些病例，最可靠的治疗方法是在严格的无菌状况下进行牙髓切除术。所以，即使症状学和诊断性测试的结果都提示患牙为可逆性牙髓炎，当临床检查发现存在龋损露髓时，就应将诊断更改为不可逆性牙髓炎。可以将诊断转变为不可逆性牙髓炎的其他的临床发现包括严重的牙周病损、“老化”钙化牙髓以及存在明显的旧有损害等。

推荐读物

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3 根管治疗：临床治疗成功的定义及如何取得治疗成功

基本原则

前两章介绍了不同形式的牙髓病治疗方法，包括只对牙髓进行表浅治疗或只治疗冠髓的活髓治疗术，以及对根管本身（活髓或死髓）进行治疗的根管治疗术。后一种方法只适用于治疗那些诊断为不可逆性牙髓炎或牙髓坏死的牙齿，也是本章要论述的主题。在某些情况下，出于修复或其他的原因，也会对健康的活髓牙进行根管治疗。

取得治疗的成功

治疗成功的标准是什么

如前所述，根尖周炎是医师进行牙髓治疗时最关注的病变过程，因而，根管治疗后不出现根尖周炎是界定治疗是否成功的惟一标准。这样，对活髓牙来说，其治疗目的在于防止发生根尖周炎，维持根尖周组织无病变就算治疗成功。但在牙髓坏死的牙齿中，临床或影像检查会发现明显的根尖周炎病变，只有在适当的时间内消除病变治疗才算成功（图3–1）。

值得注意的是，虽然治疗时间、利润、术后疼痛等都是患者和医师可以用来对治疗方法进行评估的短期指标，但它们不能取代衡量治疗成功最重要的长期指标——不发生根尖周炎。



图 3-1a 牙髓治疗成功。患牙因不可逆性牙髓炎进行根管治疗，虽然治疗的质量较差，但术后 2 年的 X 线检查确认治疗成功

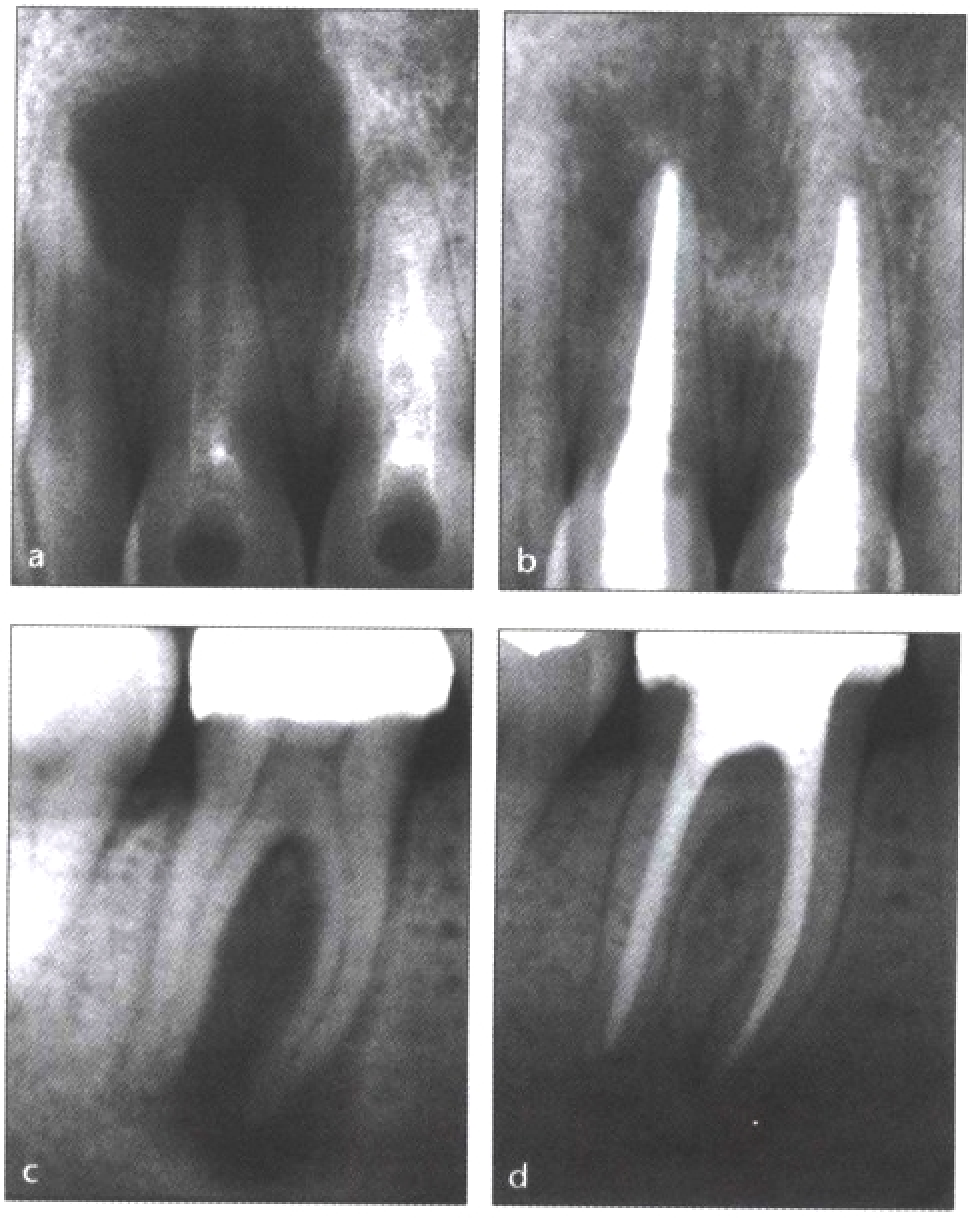


图 3-1b 根管治疗 2 年后检查显示根尖周炎病变完全愈合（a、c 术前；b、d 术后）

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取得成功的必要条件是什么

死髓牙的根尖周炎是由根管腔中的微生物引起的；活髓牙不会造成根尖周炎，一般认为其根管未受感染。这样，在患者免疫功能正常的情况下，根管治疗后形成的无菌的根管腔环境应能保障根尖周炎痊愈（感染的死髓牙）或不会发生根尖周炎（活髓牙）。对照转归研究的结果支持这一理论。对曾被诊断为根尖周炎的死髓牙进行根管治疗，并与活髓牙的治疗结果进行比较，发现活髓牙的成功率较高，也就是说，较多的活髓牙根管治疗后未发生根尖周炎（95% 对 80%）（图 3–2）。

细菌和预后

存在和不存在透射区的根管治疗成功率比较

	无透射区	有透射区
Strindberg(1956)	89%	68%
Seltzer 等 （1963）	92%	76%
Kerekes 和 Tornstad(1979)	94%	84%
Sjögren 等 （1990）	96%	86%

图 3–2 存在和不存在 X 线透射区的牙根对照转归研究结果

细菌和预后

根充前细菌培养阳性（+）和阴性（–）的根管治疗成功率比较

	培养结果（+）	培养结果（–）
Engström 等 （1964）	76%	89%
Zeldkow 和 Ingle （1963）	83%	93%
Oliet 和 Sorin （1969）	80%	91%
Byström 等 （1987）		95%
Sjögren 等 （1997）	68%	94%
Bender 等 （1964）		无差别

图 3–3 根充前根管细菌培养阳性或阴性的对照转归研究结果

死髓牙的治疗成功率低15%说明对其感染根管的消毒效果不好。另外，一些对根充前根管进行细菌培养的研究显示，细菌培养阳性的牙齿比培养结果阴性牙齿的根管治疗成功率低，后者的成功率持续高于90%（图3–3）。

当然，培养不可能检出根管内所有的细菌，许多细菌培养阴性的根管中实际上存在一些细菌。尽管如此，已经明确的是，细菌量低于一定限度后，根管诊疗的成功率能够达到相当高的水平，可用其衡量所有治疗方法的有效性。

小结

根充时根管腔中的细菌越少，根管治疗的成功率越高。如果根管治疗后管腔细菌培养持续（试验性）阴性，其治疗结果的成功率应在90%以上。

根管治疗的不同阶段

根管治疗过程分成两个阶段，微生物控制阶段和充填阶段。

微生物控制阶段

这个阶段通常被称为生物机械清理，化学机械清理，或清理和成形。这些名词都涉及到根管治疗技术，其目标是在根充前将管腔内微生物数量降低到最低水平。值得注意的是，只要采取一切可能的措施使根管在根充前达到无菌状态，所用的技术方法并不重要。只有在根管感染得到最大程度的控制后，才可进行根管充填。

因此，根管治疗术第一阶段的生物学目标是清除管腔中的所有微生物。这一治疗不应过分弱化牙根的结构，影响到对患牙的修复。

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活髓牙

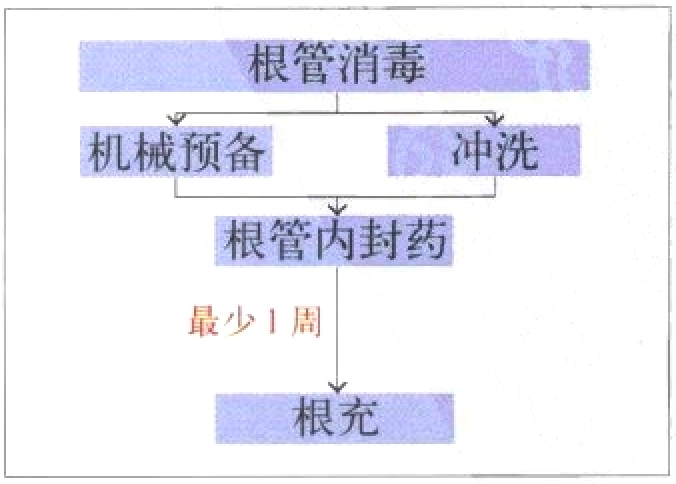
由于活髓牙的根管在进行治疗之前是无菌的，这类牙齿的治疗原则理论上很简单，那就是确保治疗结束后根管内无菌。这样，只要在整个治疗过程中保持严格的无菌操作，使用哪种根管预备方法并不是非常重要。如果采取了有效的消毒措施，且预备结束后根管腔仍保持无菌，就理应尽快用永久修复材料充填预备好的根管腔和髓腔通路。如果时间充裕，允许进行细致的操作，根管治疗的两个阶段（微生物控制和根管充填）可在一次治疗中完成，如有可能，也可同时进行冠修复。

如果时间不够，不能在一次诊疗中完成整个根管治疗程序，就应像处理死髓牙那样（见下面章节），进行管腔封药，预防再感染。

死髓牙

与活髓牙不同，死髓牙在开始治疗前几乎都已感染。虽然治疗这类牙齿也必须运用无菌方法，但要达到感染控制阶段的治疗目的，还必须采取旨在清除根管内存留细菌的消毒措施。可通过以下过程实现对根管的消毒：机械预备，抗菌液冲洗，复诊间期根管内封药，最后充填根管本身，将残余的微生物和周围的牙周组织隔离开来，以促进病变愈合（图3–4）。即使是技术最娴熟的

图 3–4　坏死（感染）根管的治疗原则



牙髓病科医生也不可能一直单靠机械预备和冲洗就能有效清除根管内的细菌，因而，为了实现根管治疗感染控制阶段的目标（尽可能减少微生物的数量），建议在第二次复诊完成根管充填之前，应进行至少 1 周以上的根管内封药消毒。

不锈钢锉和逐步后退法成形

预备感染根管的传统方法是使用不锈钢锉和逐步后退(step—back technique)成形。操作中，用 25 号锉达到工作长度后，用 30 号锉扩至比 25 号锉短 1mm 的部位，再用 35 号锉扩至比 30 号锉短 1mm 的部位，不锈钢锉每增加 1 号，其扩根深度减少 1mm，直至完成从根尖到根管口的根管预备（图3—5）。再用锉平滑根管壁上形成的台阶，将根管预备成圆锥形，最窄处位于根尖孔，管腔径由根尖到根管口逐渐增大。

虽然使用逐步后退法比较安全，较少发生操作差错，但在微生物控制阶段最关键的一点上，这种方法却达不到要求：锉针在根尖段的直径太小，不足以使细菌的数量减少到最低限度。由于这种原因，采用这种技术治疗感染根管的成功率较未感染的活髓牙降低 15% 左右（图 3—6）。

不锈钢锉可以预弯，但随着直径的增加，锉的柔韧度逐渐降低（图 3—7）。一般认为，大号锉缺乏柔韧性是造成大部分差错（如根尖区阻塞，根管直化，形成肘部，条状侧穿等）的主要原因。不过，作者认为，最终造成多数根管失败的原因并非不锈钢锉缺乏柔韧性，而是根尖至冠部的预备通路。在这一通路中，小号锉可以到达未预备根管的根尖孔附近，此时，锉针从根尖到根管口全程与根管壁接触。预备开始后，在整个管腔中产生大量的牙本质碎屑。为了保持根管不被阻塞，以便用大一号的根管锉进行预备，首先必须将前一锉针产生的碎屑全部清移出管腔。另外，为了避免出现根管阻塞和发生前面提及的差错，

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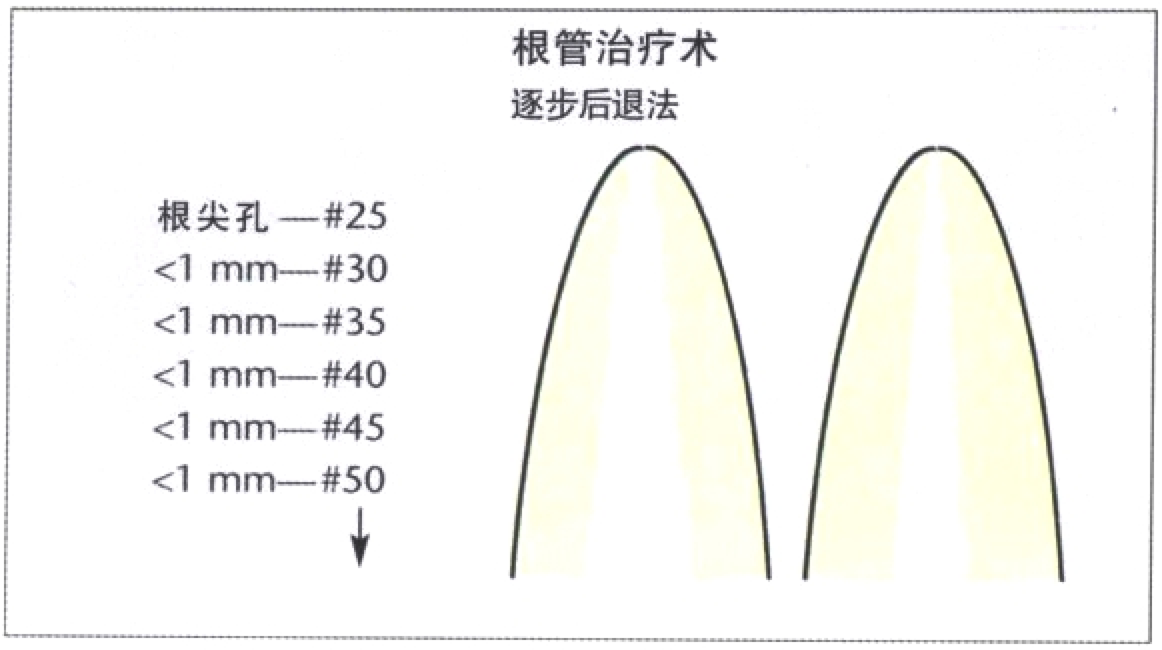


图 3–5 逐步后退技术

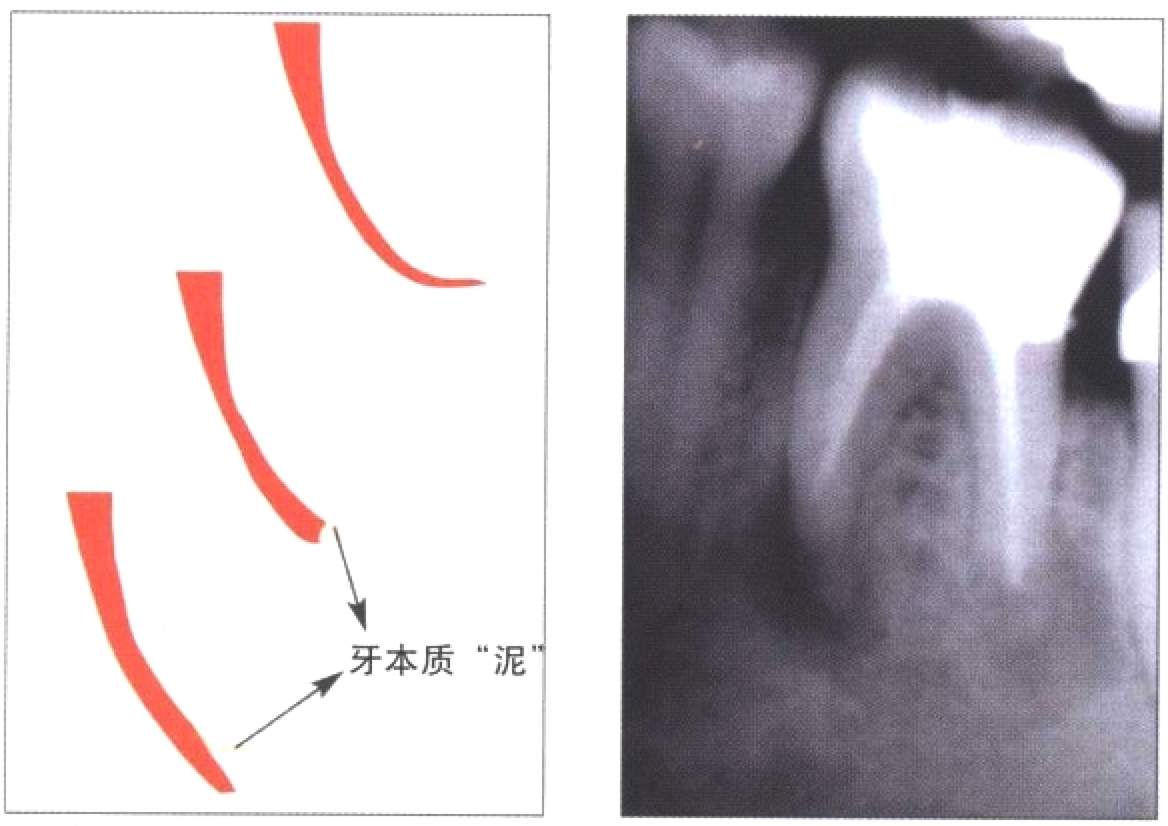


图 3–6 根向堆积牙本质碎屑作用。使较大号的锉针偏离根管实际走向，造成根管直化甚至侧穿

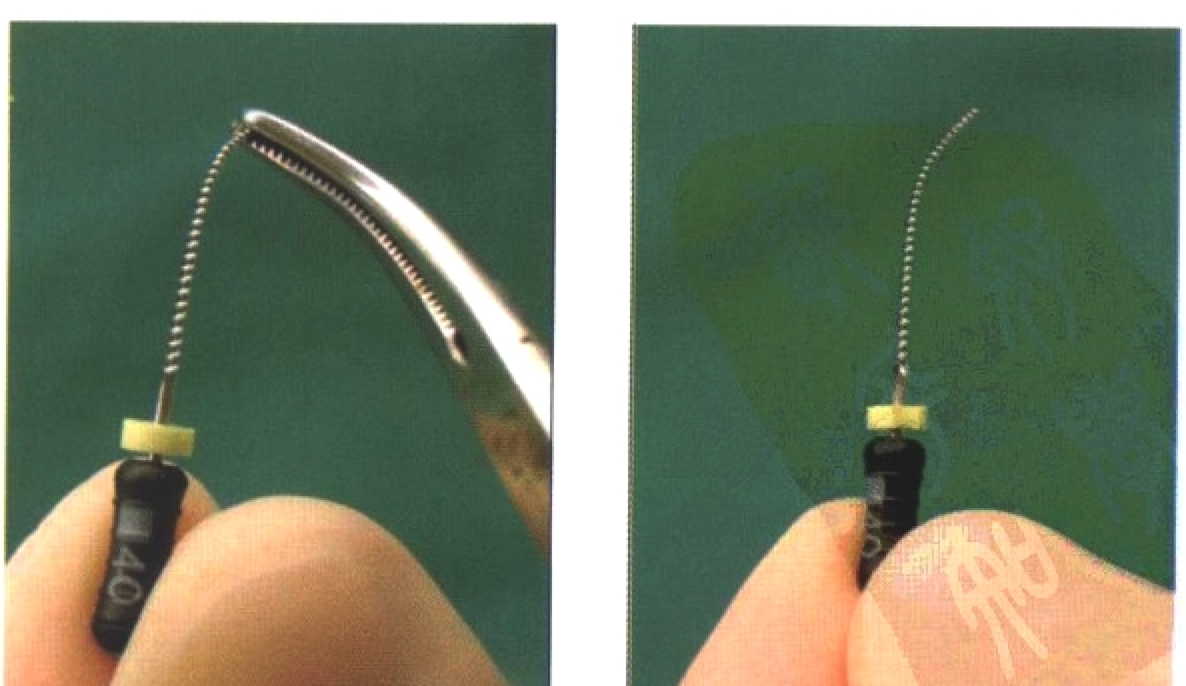
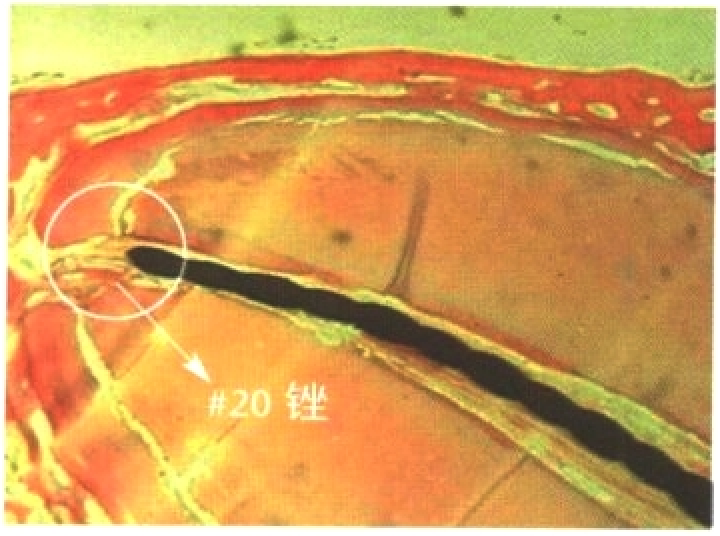


图 3–7 用止血钳弯曲一 40 号不锈钢锉。锉缺乏柔韧性，保持其弯曲后的状态



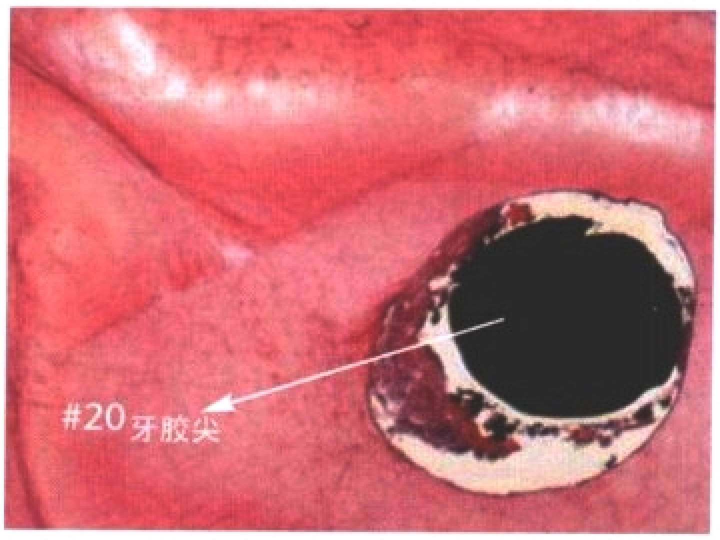


图 3－8　逐步后退法。注意，即使是在最细的根管中，根管的实际直径和 20 号的锉（左）或牙胶尖直径之间也存在明显的差别

必须朝冠方而不是根方清移这些碎屑。不难看出，随着用10号锉开始进行预备，依次扩大到到 40 号或 50 号锉时，根尖段将被牙本质碎屑阻塞，造成管腔变短或直化（图 3–8）。这不是器械缺乏柔韧性的结果，而是依次使用 40 号或 50 号锉冠向外移所有碎屑的累积结果。因而，逐步后退法成形难以达到根管治疗感染控制阶段的生物学目标。

改良逐步后退法成形

为了克服逐步后退法成形的缺陷，推出了改良逐步后退法成形技术。由于逐步后退法成形过程比较安全，不易出错，使用改良法操作时首先完成这一过程；用 25 号锉预备到工作长度后，再继续扩大根管的根尖1/3，使这部分管腔的直径达到更有利于彻底清理的尺寸（图 3–9）。于是，将 30 号锉等依次预备到工作长度，逐步扩大根尖 1/3 段。由于先前用传统逐步后退法使根管的冠 2/3 得到充分的扩大，再用较大号的锉预备根尖部分并不困难。此时，大号锉针可以深入至工作长度，只与根尖段 3～4mm 的管壁接触，根管预备产生的牙本质碎屑较锉针与整个管壁都接

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触时少得多，而且，已扩大的管腔非常有利于牙本质碎屑的冠向（而不是根向）清移。在使用不锈钢锉的情况下，利用改良逐步后退技术能够较传统逐步后退法取得更加确定的微生物控制效果（图 3–10）。

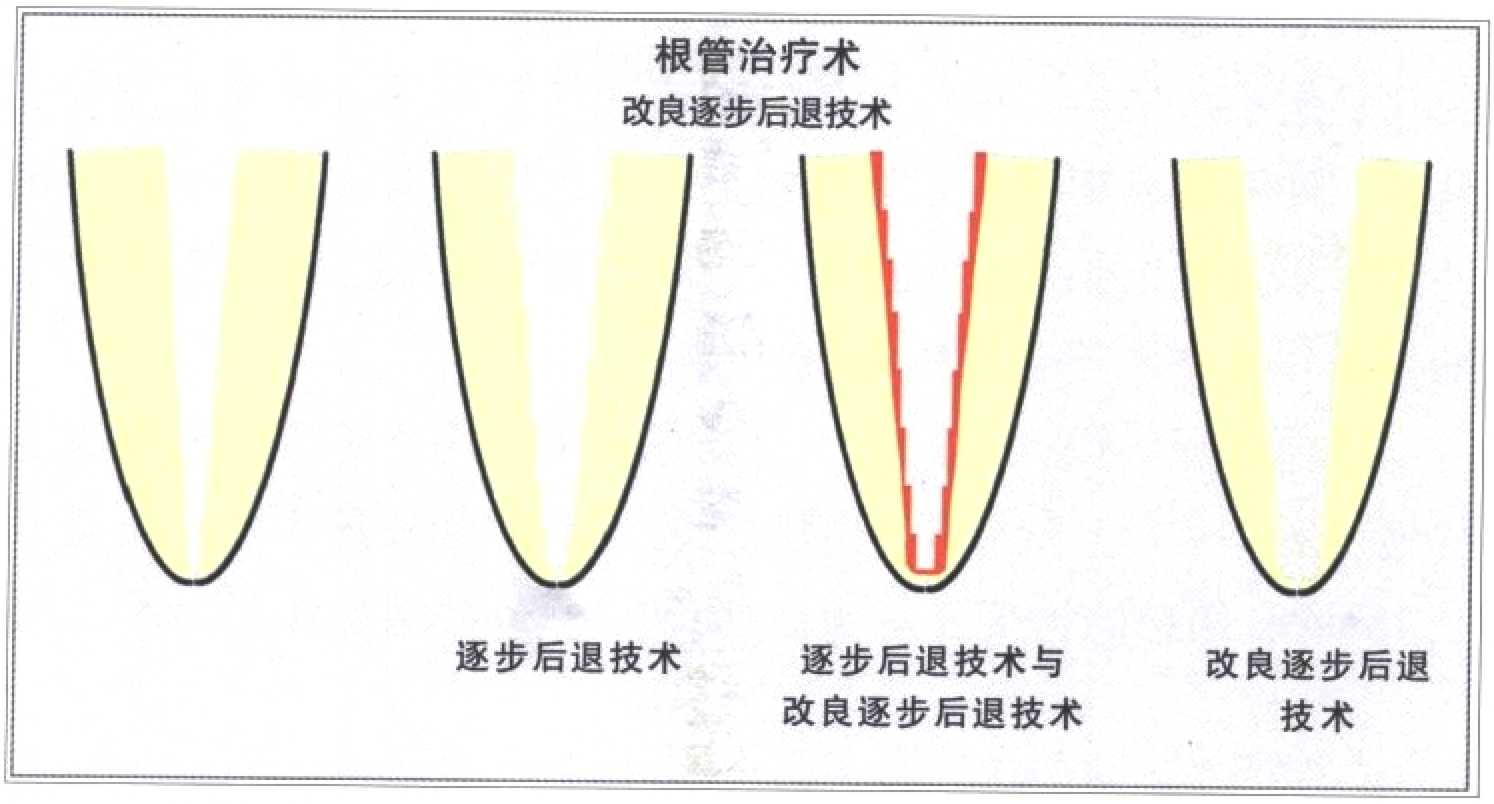


图 3–9 改良逐步后退技术。先进行逐步后退成形，再将根尖 1／3 的直径扩大到生物学可接受的尺寸

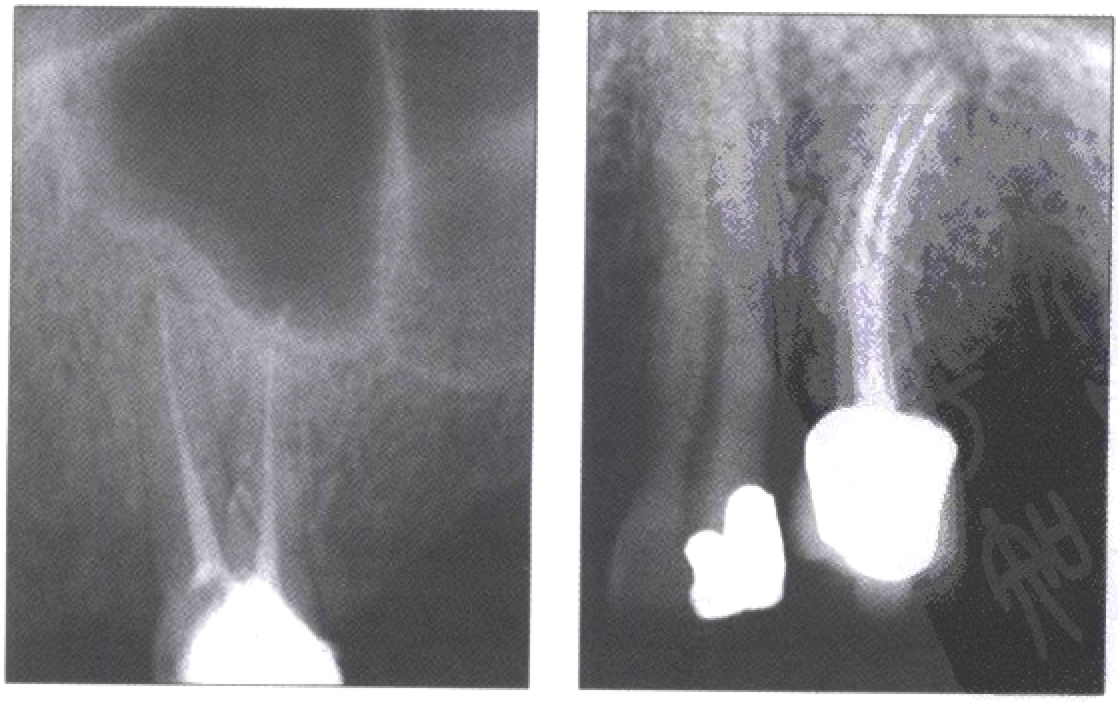


图 3–10　接受传统逐步后退技术（左）和改良逐步后退技术（右）治疗的 X 线片结果比较

使用镍钛锉的逐步深入技术（*Crown-down technique*）

过去的几年中，用于根管治疗细菌控制阶段的器械出现了一些革命性的变化，其中最重要的当属镍钛金属锉的应用。镍钛锉极度柔韧和富有弹性。另外，镍钛锉在受张力作用时弯曲，一旦去除张力，锉会"弹回"到原来的大小和位置（图3-11）。因而，这种器械能够轻易地沿根管的曲度预备管腔，而这对不锈钢锉来说几乎是不可能的。这种金属的缺点之一在于其塑性点上，也就是说，其伸展点和断裂点非常接近。这意味着镍钛锉会在无明显外表警示迹象的情况下发生断折。不过，如果医生依照使用说明细心操作，基本不会发生器械断裂。

近年来锉针设计上的另一个变化是锉针切割长度和锥度的多样性（图3-12）。对于不锈钢锉，无论锉的全长是多少，其切刃长16mm，切刃的锥度递增为0.02mm/mm（共增加0.32mm）。而

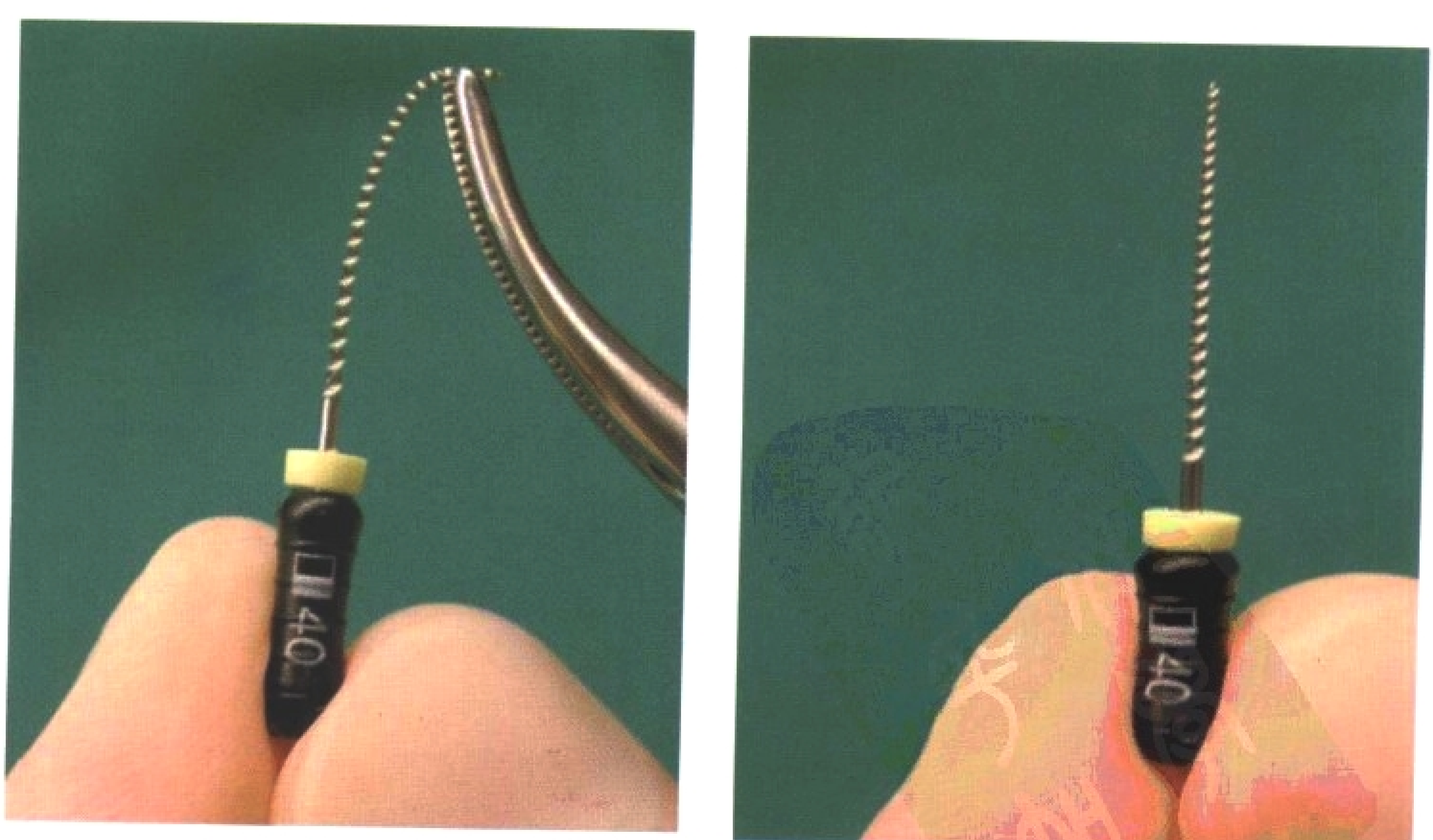


图3-11　用止血钳弯曲一40号镍钛锉。由于锉针极富弹性，松开后锉针弹回原来的状态

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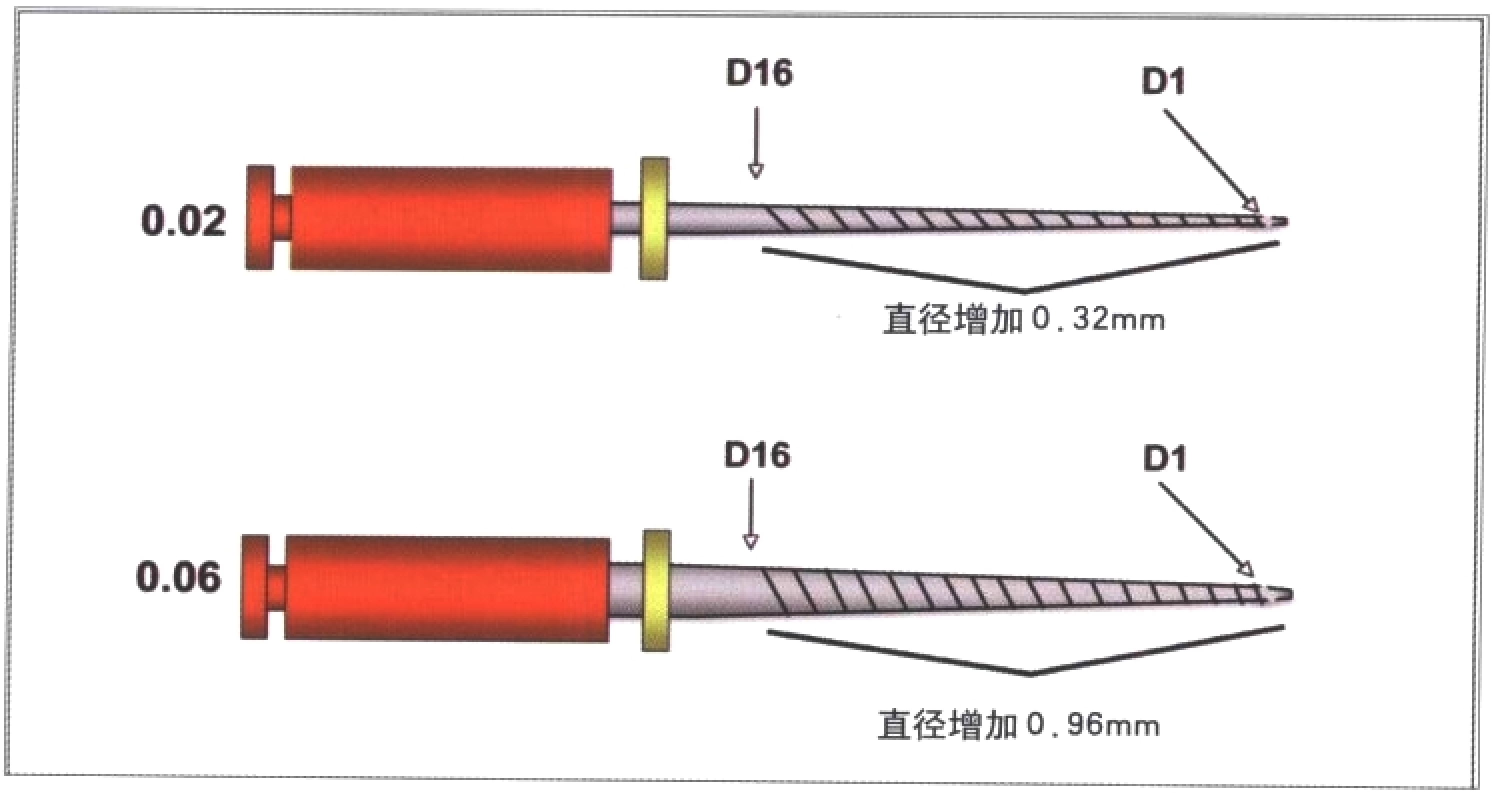


图 3-12 不同的锥度

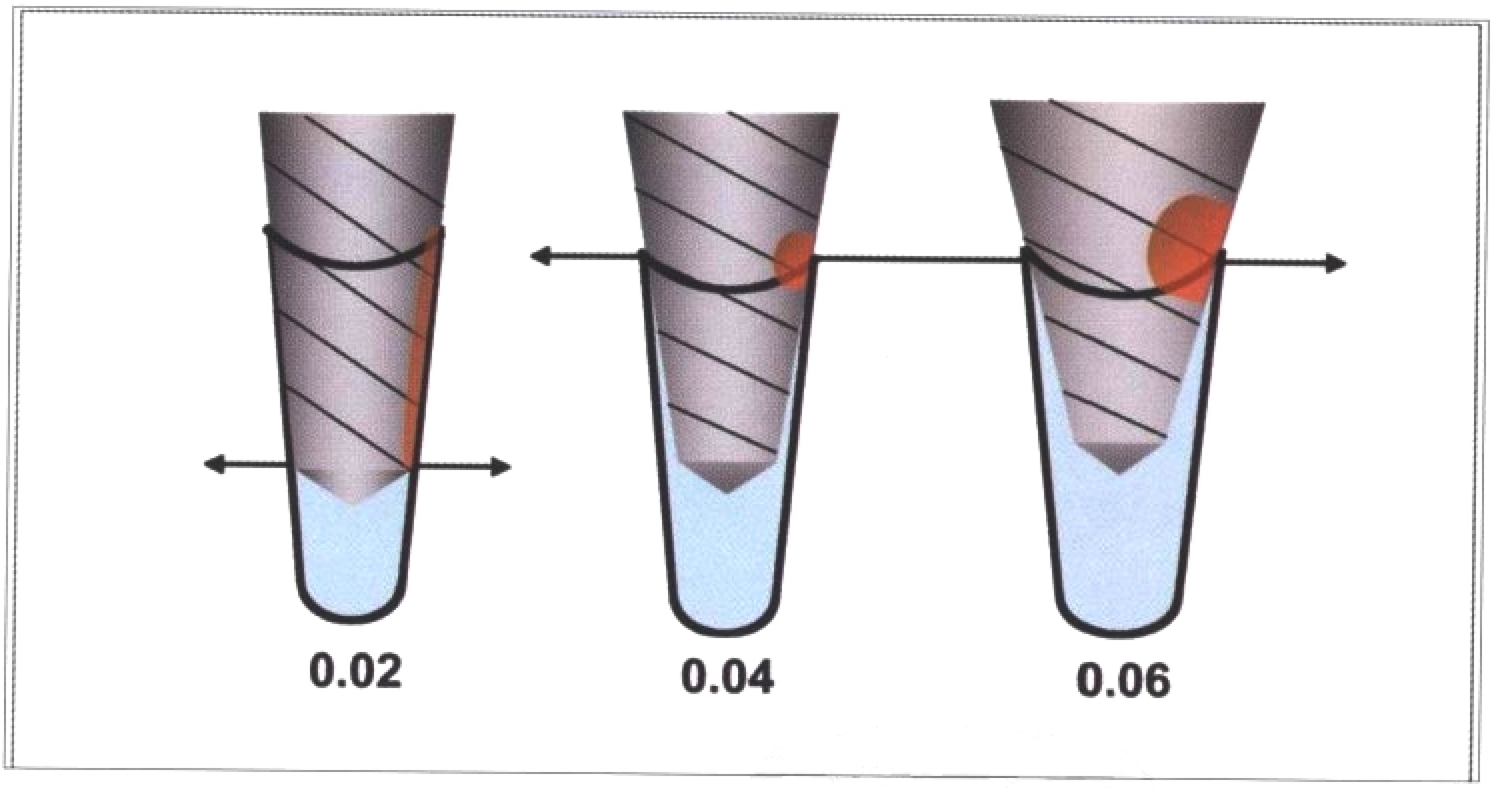


图 3-13　锉针锥度对锉针与根管壁表面接触形式的影响。注意锥度较低时余留的根向空隙较少，导致较多的碎屑被推向根尖方向；高锥度则导致较多位于接触点冠方的牙本质被切除

现代锉针的切刃和锥度多种多样，从0.02mm到1.2mm/mm不等。大锥度锉的缺点在于其越深入管腔，不必要切除的冠方牙本质越多，形成楔形管腔，使牙齿容易发生牙折（图3-13）。因而，必

须牢记高锥度锉针只能用于预备根管的冠向部分，随着预备的根向深入，应换用锥度较小的锉针。

随着不同锥度锉针的出现，现在可以由冠方到根尖方向进行根管预备，称为逐步深入技术（crown–down technique），而不用前面介绍过的逐步后退技术。使用逐步深入法预备时，选择一锥度能够轻松插入自然管腔的锉针，深入管腔大约4mm时，其锥度大于根管的锥度，锉针在根管口处与管壁接触。此时手动或机动旋转锉针，每次根向深入1mm逐渐扩大根管腔，直到锉针尖端的3～4mm部分受到自然根管的管壁束缚为止。此刻，应停止用此锉继续根管预备，因为这时锉针与管腔结合的部分过多，随时可能发生断针，并将牙本质碎屑推挤到根尖。所以应换用小一号的锉针（锥度也可能较小）继续深入预备根管。由于换用了直径较小的锉针，锉的尖端在管腔中又变得不受拘束，可以继续以每次深入1mm的幅度预备根管，发生断针和牙本质碎屑阻塞的风险极低。这样，只需换用不多的锉针即可预备到工作长度。不过值得再三强调的是，使用镍钛锉和逐步深入技术时，虽然25号锉预备到工作长度的过程比用不锈钢锉容易得多，但此时的根管成形仍然是逐步后退形，我们前面已经提到这种成形达不到根管治疗细菌控制阶段的要求。因此，在预备根尖1/3部分时，还须额外重复改良逐步后退成形的过程，不过使用新一代锉针完成这一步骤比较容易。确实，用这种方式可以安全地将根管预备到比使用不锈钢锉和改良逐步后退成形更加粗大的水平。

小结

多种多样锥度的镍钛锉的出现，使根管治疗的方式发生了革命性的转变。通过由冠方到根尖方向的预备过程完成根管治疗的起始阶段，形成的顺畅通路非常有利于对根尖段管腔进行彻底的

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清理。然后用锉彻底清理根管的根尖1/3，使管腔的直径达到相当的尺寸，以确保根充前根管中细菌的数量下降到最低水平。

充填阶段

如果医生认为根管中的细菌数量已减少到最低水平，就可着手进行根管充填。如前所述，对于活髓牙，如果时间充裕，可在第一次诊疗时完成这一过程；而对于牙髓感染坏死的牙齿，应进行根管内封药，下一次诊疗时完成充填。充填阶段包括根管充填和冠部充填两部分。顾名思义，这一阶段的目的在于充填微生物控制阶段形成的根部和冠部腔隙。如果这些空隙被密实充填，残存的细菌就不能逸出到周围的组织中，根尖周组织液不会渗入到根管中为细菌提供营养，口腔中的细菌也不会再侵入根管腔。

推荐读物

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4 根管治疗术：临床操作

本章中我们假定所有的患牙已被确诊，并需要接受根管治疗。

预估工作长度

开始进行根管治疗之前，医生必须对牙齿的工作长度有一个比较准确的估计。这种预估的依据来自术前X线片，注意必须使用开始治疗前刚刚投照的X线片。为了保证X线片尽可能准确地反映牙齿的实际大小和长度，胶片必须放置的与患牙平行（图 4–1）。



图 4–1 在使用得当的情况下，用平行投照装置获得的影像能够相当准确地反映牙齿的大小和长度

使用平行投照装置能够使这项工作变得比较容易，在投照上颌牙时尤其如此。不过，必须清楚的是，这种装置只保证牙齿与X线球管头和胶片平行，医生遇到的困难是如何放置这一装置，使牙齿在球管头和胶片之间平行。投照下颌牙时，使胶片与牙齿平行并不困难，但要求患者在放置胶片时抬起舌头，使胶片滑落并与牙齿平行（图4–2）。

投照上颌牙比较困难。许多患者的腭部过于扁平，难以适当放置胶片，往往会将胶片沿腭部外形弯靠于其上（图4–3），投照时应尽量避免发生这种情况。经常必须将胶片朝腭中线方向放置，此时在牙齿和胶片之间放置一棉卷会有所帮助（图4–4）。

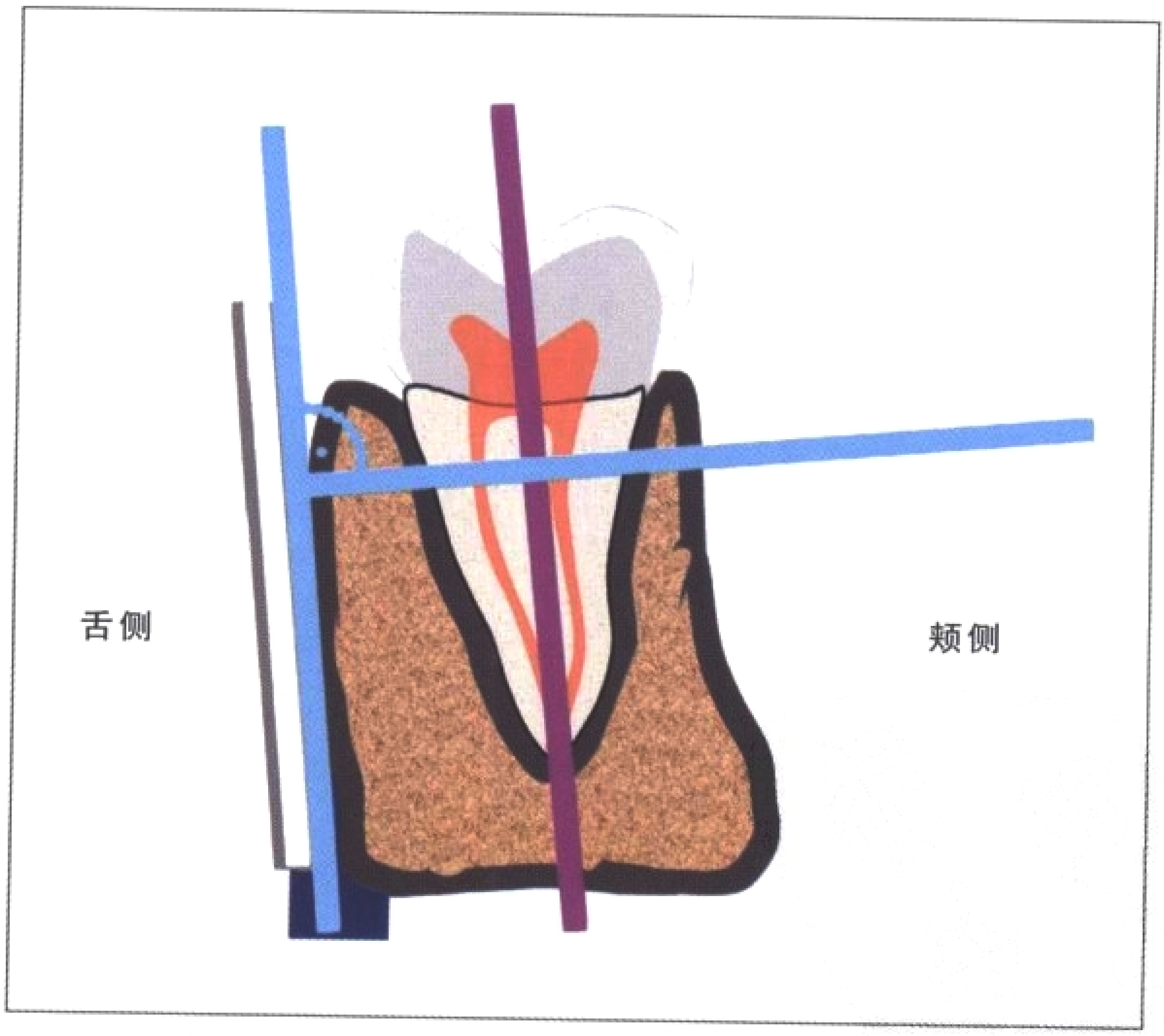


图4–2 下颌投照时胶片的放置与牙齿平行。胶片到牙齿的平行定向保障了X线影像能够准确反映牙齿的长度

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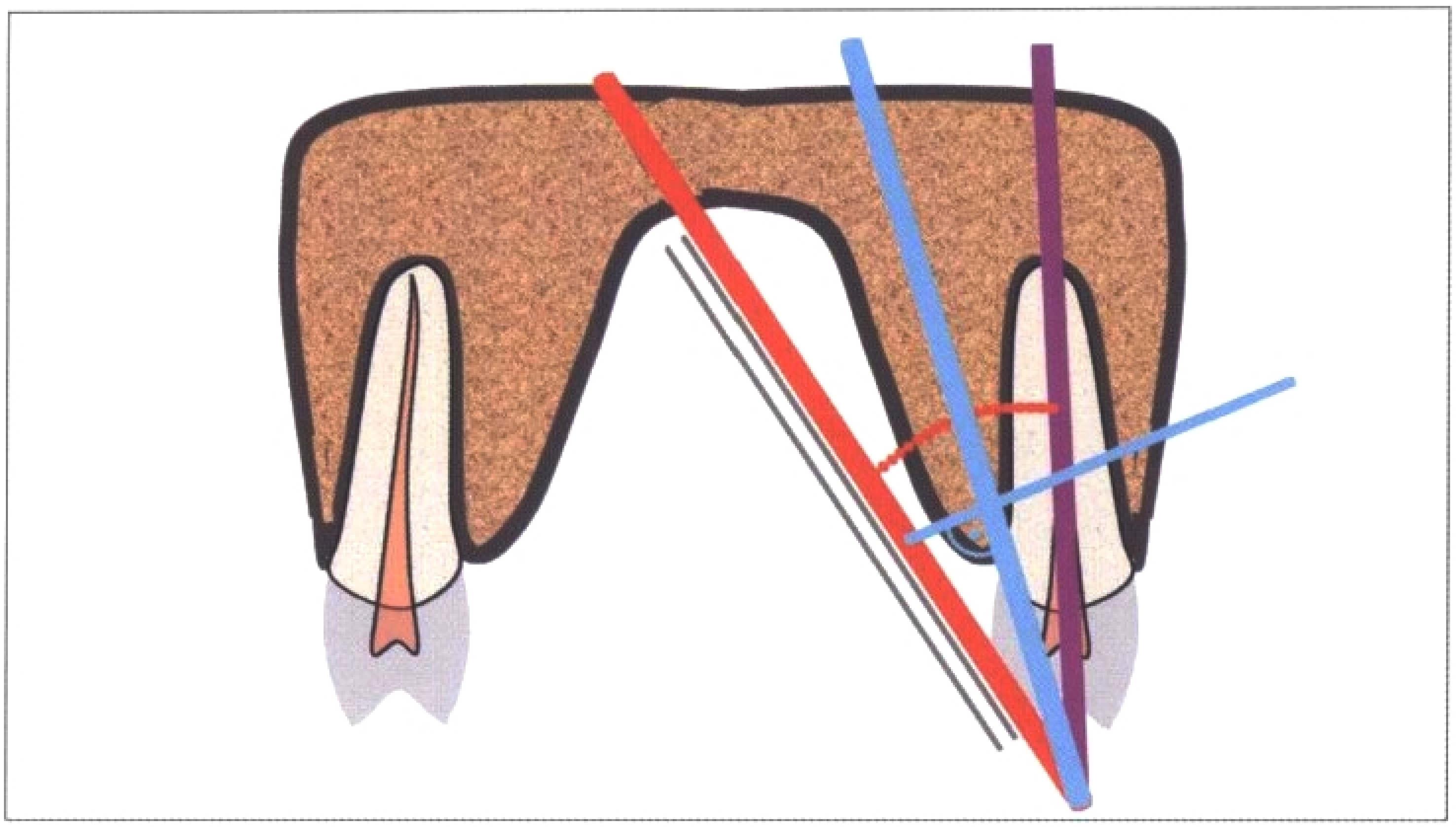


图 4–3 使用平行投照装置进行的分角线投照技术。腭部的形状使胶片放置时难以靠近上颌牙齿。通过 X 线片估算工作长度时必须将这种困难考虑进去

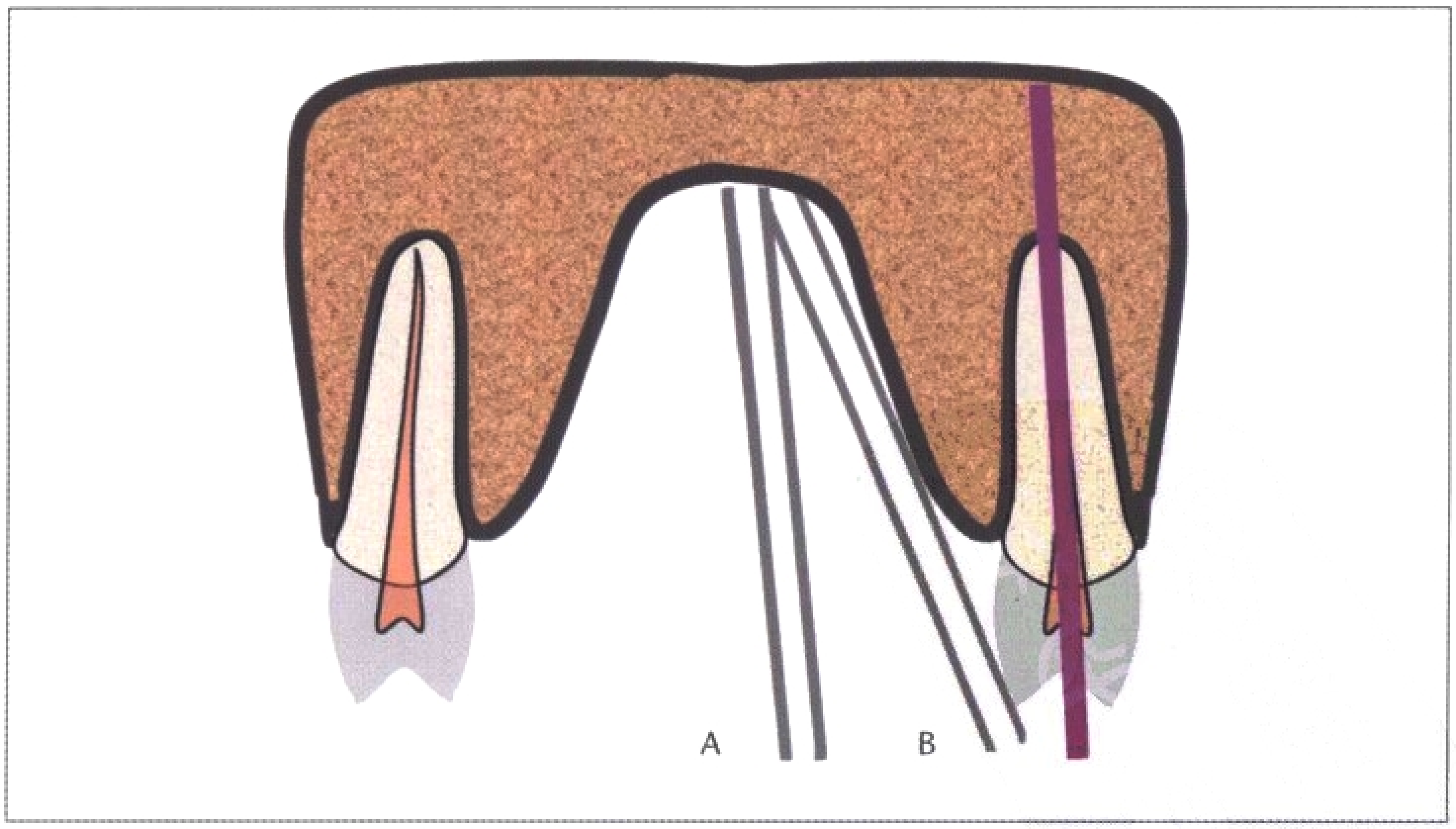


图 4–4 朝腭弓深部放置胶片可以使其与牙齿更接近平行（A）。投照时在胶片和牙齿的冠部之间放置一棉卷之类的物体有利于维持胶片的适宜位置

一旦完成水平投照，用尺子或其他数码测量装置量取X线片中牙齿冠顶到根尖的距离（图4–5）。虽然这只是一个估计长度，但这不妨碍医生参照其安全地对根管的冠2/3段进行预备，等取得准确的工作长度后再预备根尖1/3部分。

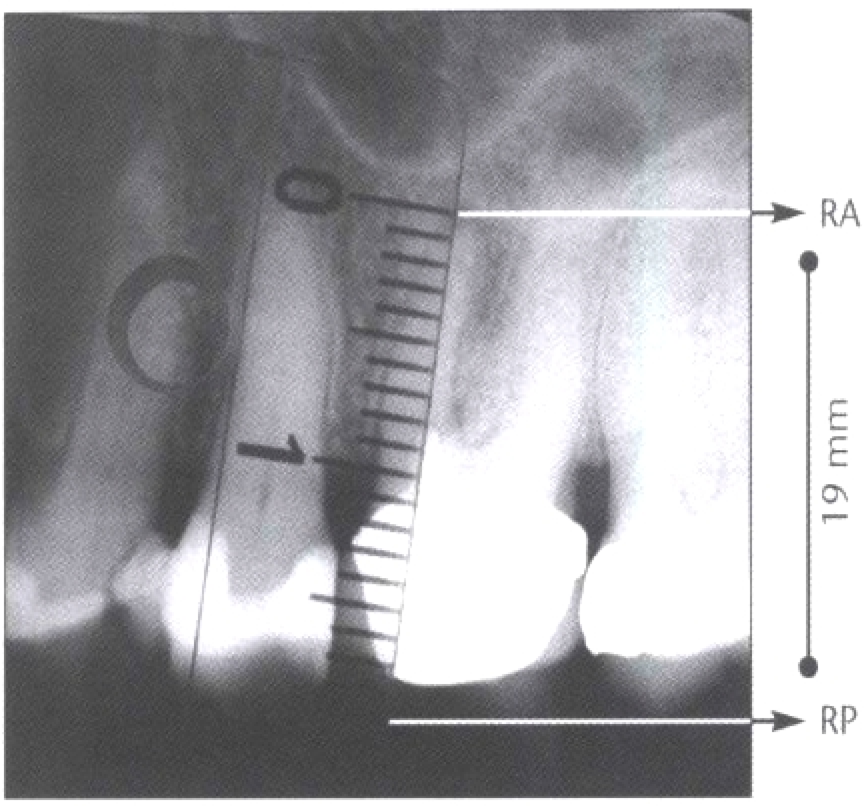


图4–5a　用尺子在平行投照的术前X线片上量取预估工作长度（RA：X线根尖；RP：参照点）

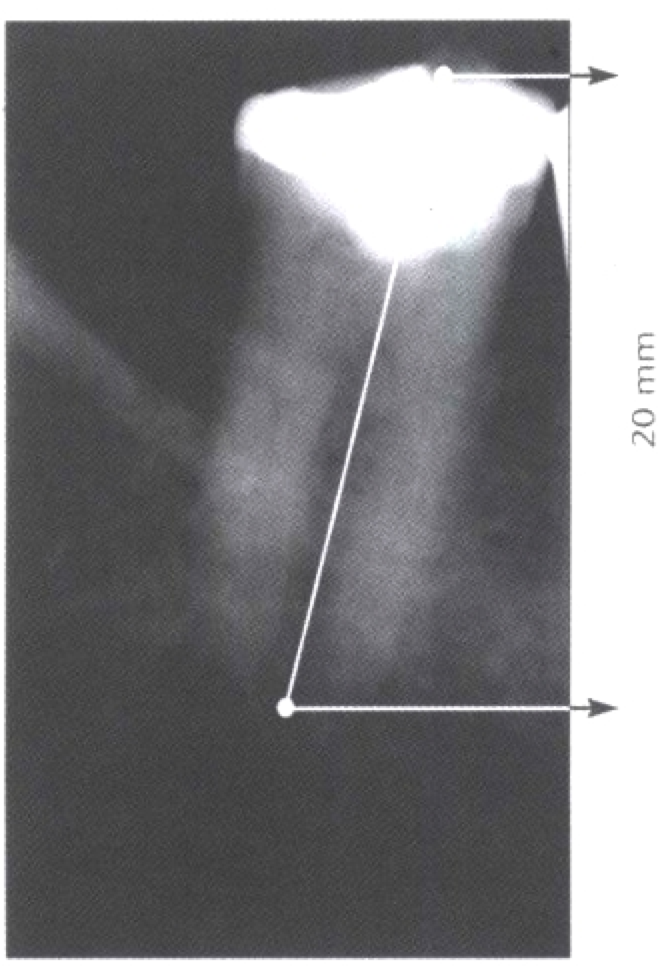


图4–5b　在平行投照的数码X线牙片上测量预估工作长度

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根管通路备洞

正确的通路是保证根管治疗成功的关键，必须要实现直线通路。实际上，适宜的通路对于镍钛锉更加重要。因为不像不锈钢锉那样，使用镍钛锉时既不能进行预弯以利于锉针进入根管口，又不能顺畅地靠着一个特定管壁推进，以防锉针折断。

各个牙齿的解剖特点和根管数目不是本手册讲述的内容，只需指出的是，离开对根管解剖知识的全面了解，就不能很好地进行根管治疗（图4—6）。还应记住一点，找到的根管永远不如要找的多。

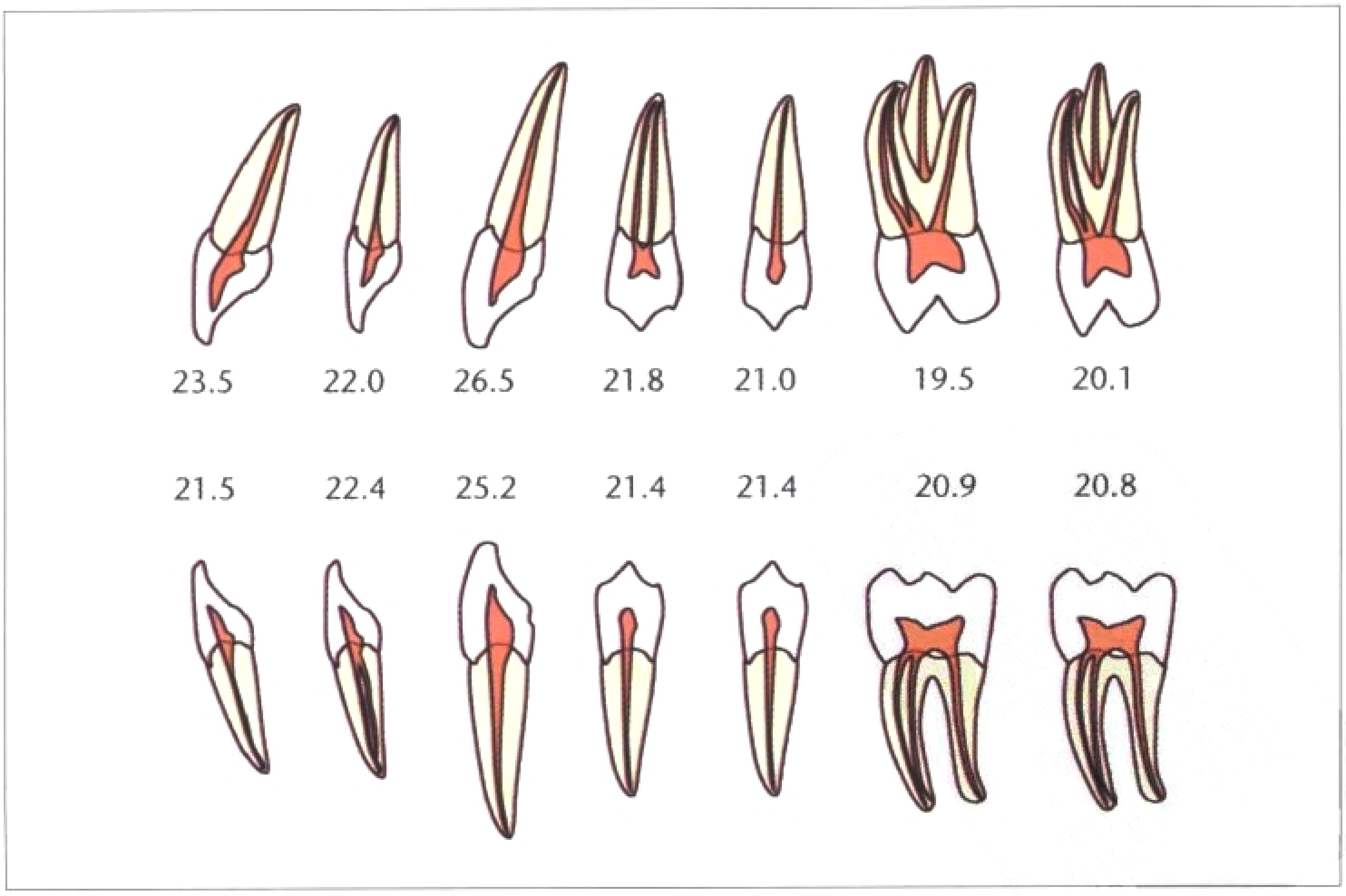


图4—6a　所有牙齿的平均长度（单位：mm）

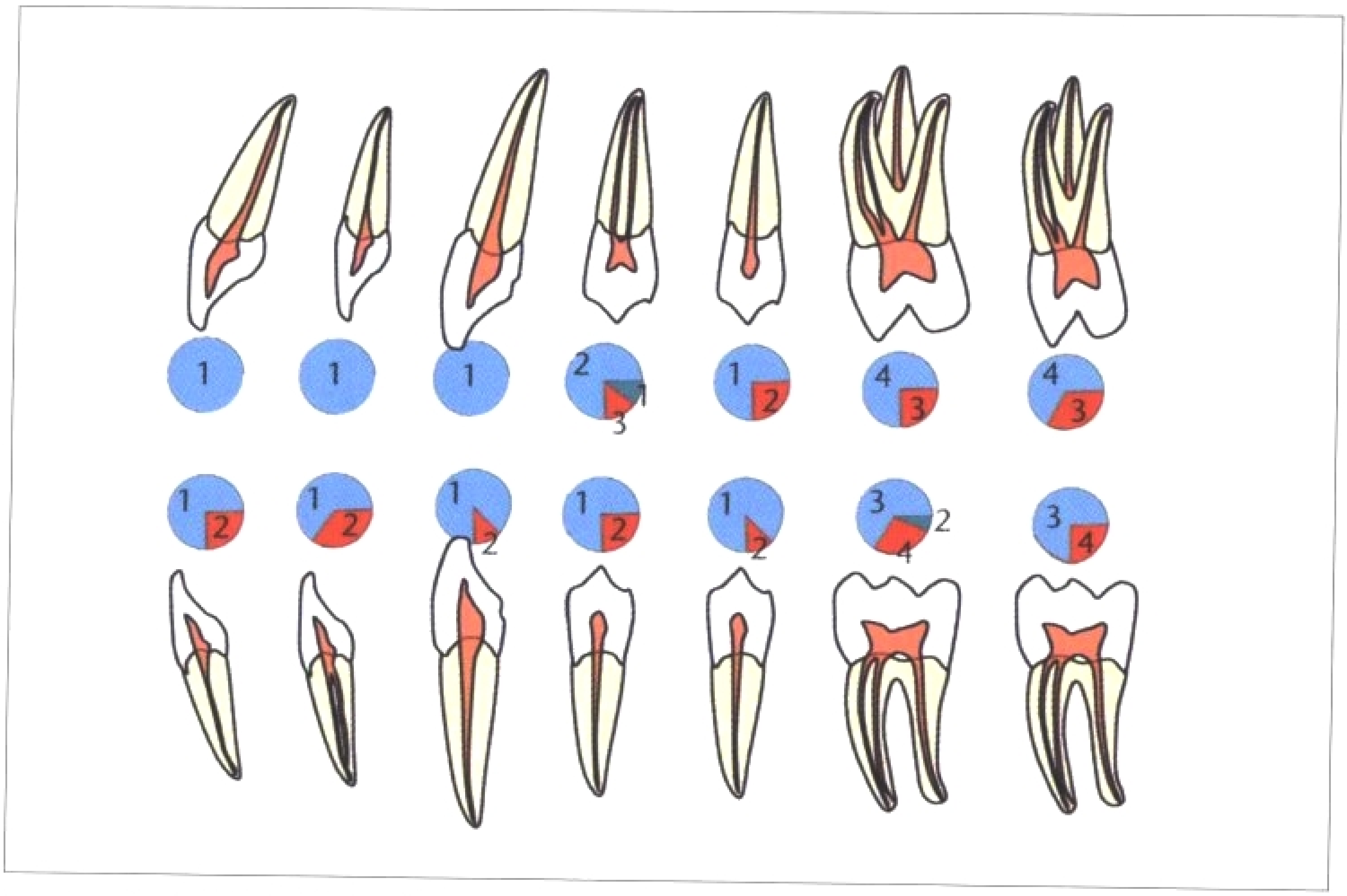


图 4－6b 各种类型的牙齿中能够找到的根管数目（频度）

以下几点提示可以帮助读者制备出适宜的通路洞形，以保障进行充分的根管预备。

1．髓腔永远位于牙齿的中央：其轮廓外形是牙齿在釉牙骨质界（CEJ）水平外缘轮廓的缩影（图 4—7）。开始进行通路备洞时，牙齿CEJ水平的外缘轮廓应清晰可见，如果对准CEJ的中央，髓腔就肯定在那里。磨穿髓室顶后，可以依照牙齿在 CEJ 水平外缘轮廓的形状去除整个髓顶。从实用的观点出发，作者建议打通髓腔后再设置橡皮障，这样可以保障能够清楚地观察到CEJ。完成通路预备并清除掉所有的龋损和不密实的修复物后，就可设置橡皮障并采取措施形成无菌环境。

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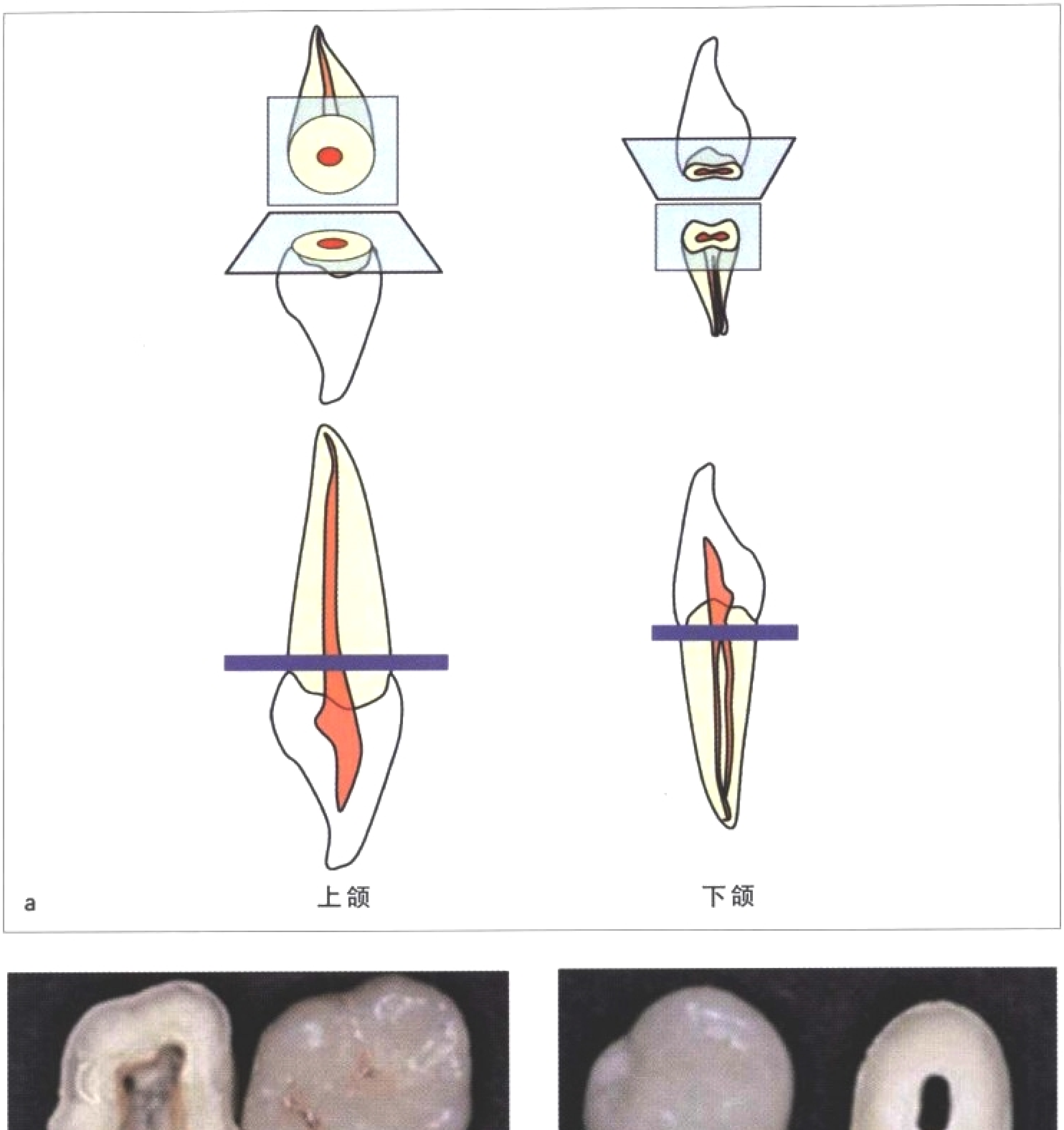


图 4－7 髓腔的形状反映牙根在釉牙骨质界（CEJ）水平的轮廓外形

2. 根管口永远位于颜色较暗的髓室底和颜色较浅的髓室壁的交界处，且通常处在暗色底线角的顶点上（图4–8）。直到暗色髓室底和浅色髓室壁的交界清晰可见，通路预备才算充分。如果看不清这一交界，说明髓室顶还没有被全部磨除。此时，就应去除整个髓顶扩大通路。通路扩大到适宜的程度后，就可用探针在髓底线角的顶端探寻根管口的位置。只有在证实根管口已经钙化的情况下才能用钻针磨切髓室底组织。绝大多数情况下，可用探针找到根管口。

3. 在多根管牙中，根管口相互对称（图4–9）。如果在髓底近远中向假想线的一侧找到一个根管口，那么，可以预期在此线对面相等的距离上找到另一根管口。如果根管口正好处于这条线上，则极有可能只有这一个根管口，可不必费时再去寻找。



图4–8 根管通路洞形的殆面观。浅色室壁与深色髓底交汇；根管口位于暗黑的髓底线角处。如果看不到暗色髓底与浅色髓室壁之间的交界部位，说明通路洞形预备得尚不充分

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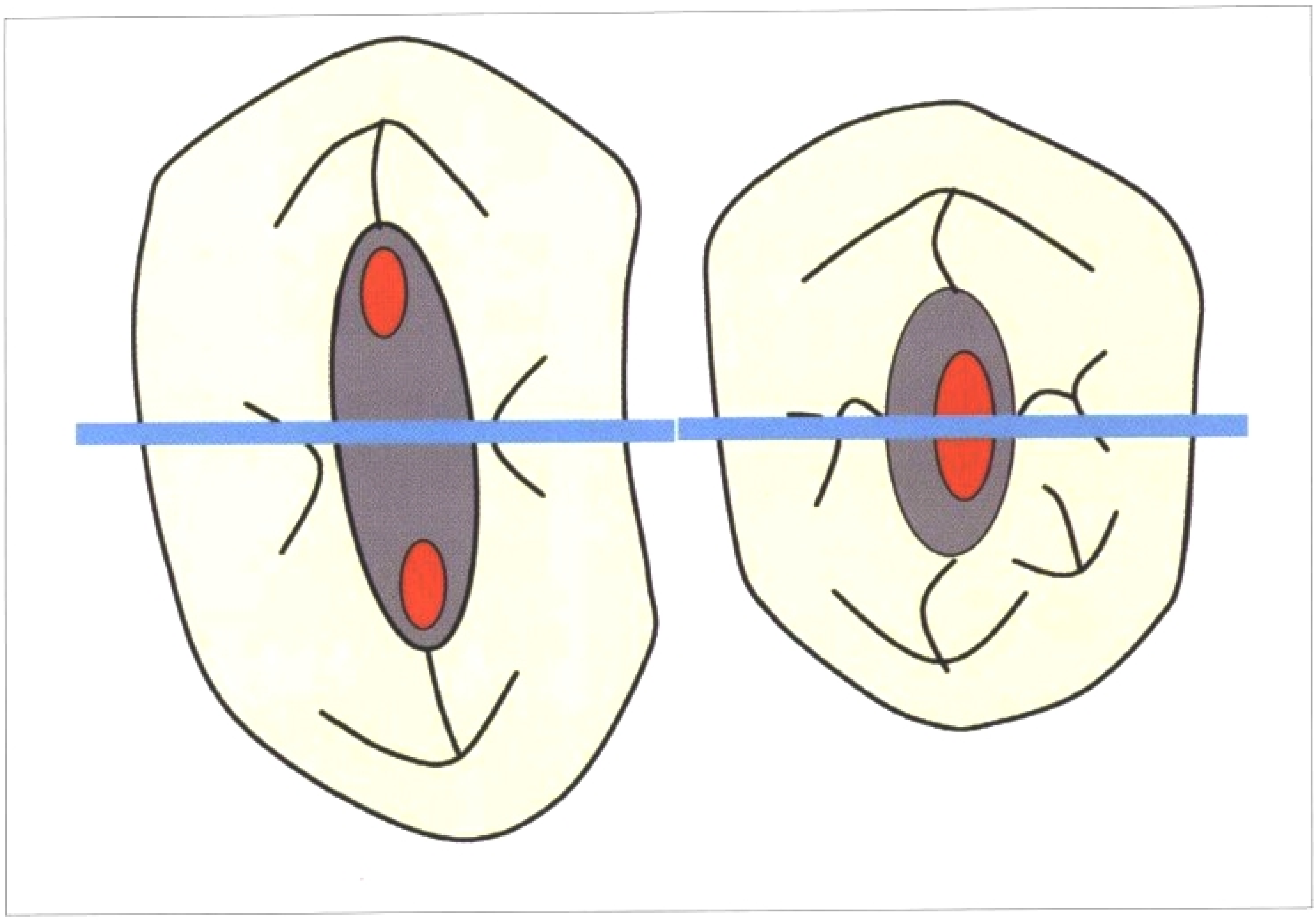


图 4-9 根管口的位置相互对称



无菌操作

由于保障根管治疗成功的关键在于根充前控制根管中的菌落，采取措施使治疗过程中根管免受污染至关重要。无菌操作是关键。虽然无菌概念在理论上非常简单，但由于肉眼看不到细菌，实施严格的无菌操作在临床上却十分困难。遵循以下几点基本规则可以帮助医生和医助更有效地开展无菌操作。

1. 将治疗过程分为“污染”和“洁净”两个阶段。污染阶段的治疗在设置橡皮障之前进行，包括制备通路开口和去除一切龋损和有问题的修复物。进行这些操作时不应打任何折扣，在残留有龋损的情况下不可能维持无菌的环境。另外，如果牙齿已不可修复，应在开始治疗前发现这一点（图 4–10）。清除掉龋损和发

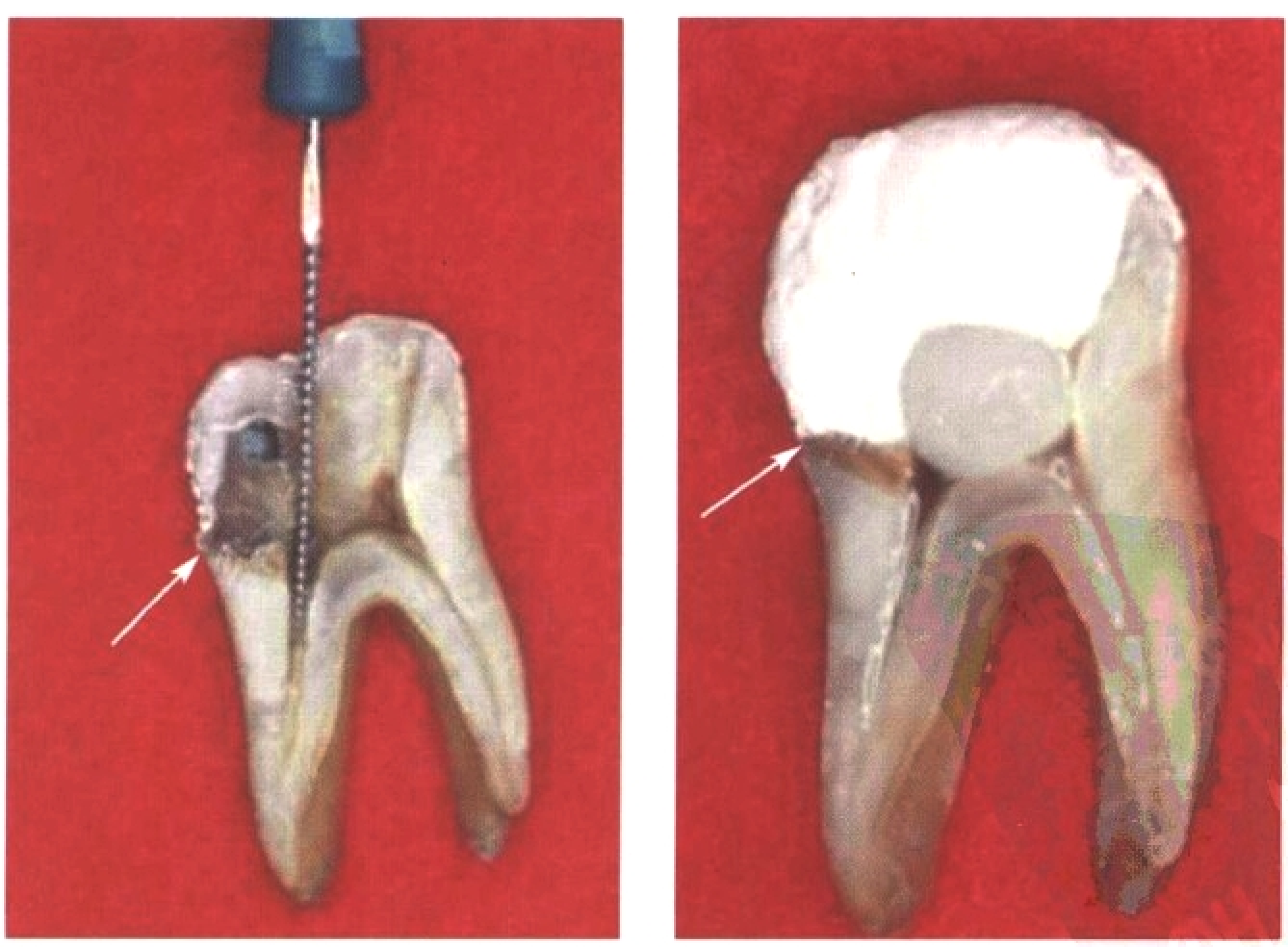


图 4–10　牙髓治疗过程中或放置暂封材料后仍有龋损残留。在这种情况下，根管治疗的基本目标和细菌控制注定不会实现

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生渗漏的修复物后，如果认为牙齿是可以修复的，就应马上设置橡皮障并封闭患牙的四周，以防止唾液渗入（图 4–11）。

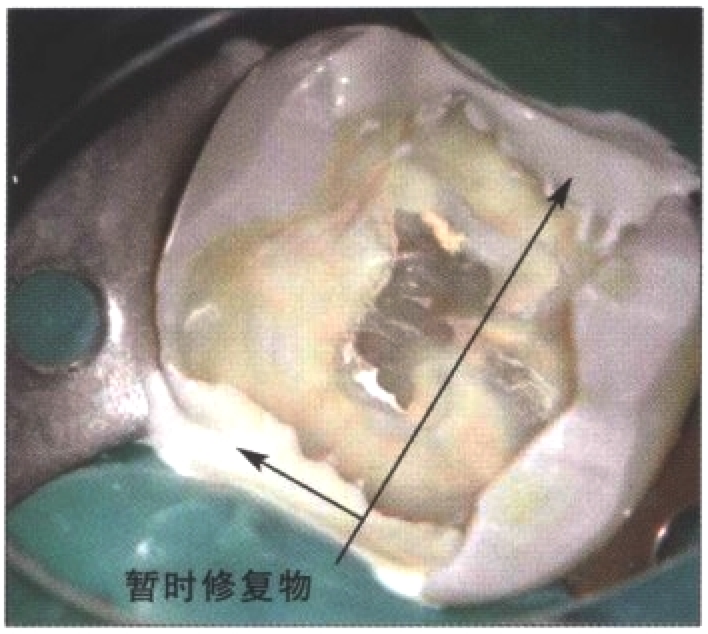


图 4–11　去除龋损和有问题的修复物，封闭橡皮障以防止唾液污染





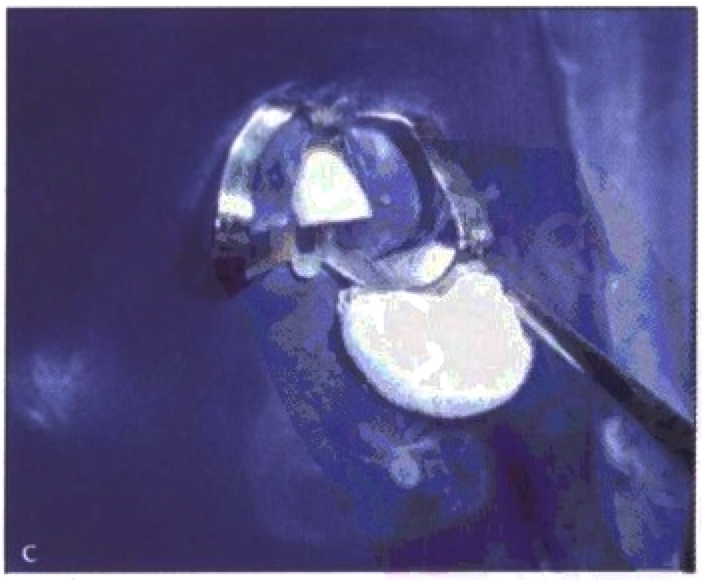


图 4–12 无菌操作。(a) 未设置橡皮障的通路；(b) 设置橡皮障 (c) 用氯己定或聚维酮碘消毒手术野

2. 对通路窝洞和周围 2cm 范围的橡皮障进行消毒（图 4–12）。常用的消毒药剂是氯己定和聚维酮碘。从此刻起，所有进入根管的器械都应是消毒过的。

3. 将工作区本身分为“污染”和“洁净”两个区域，以保持无菌。不要用手接触锉针（图 4–13）；要用消毒过的镊子或类似的器械弯曲锉针。

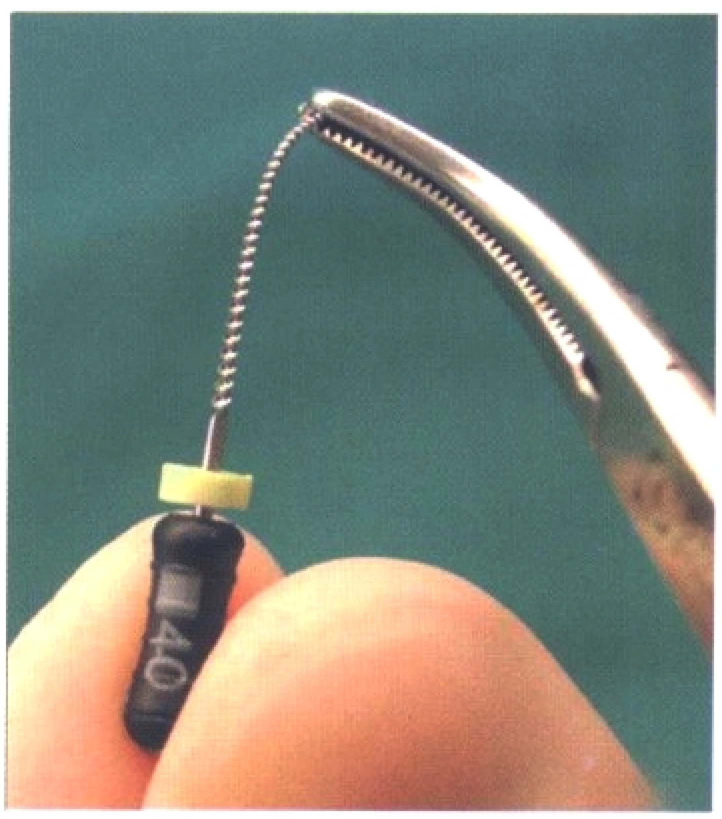
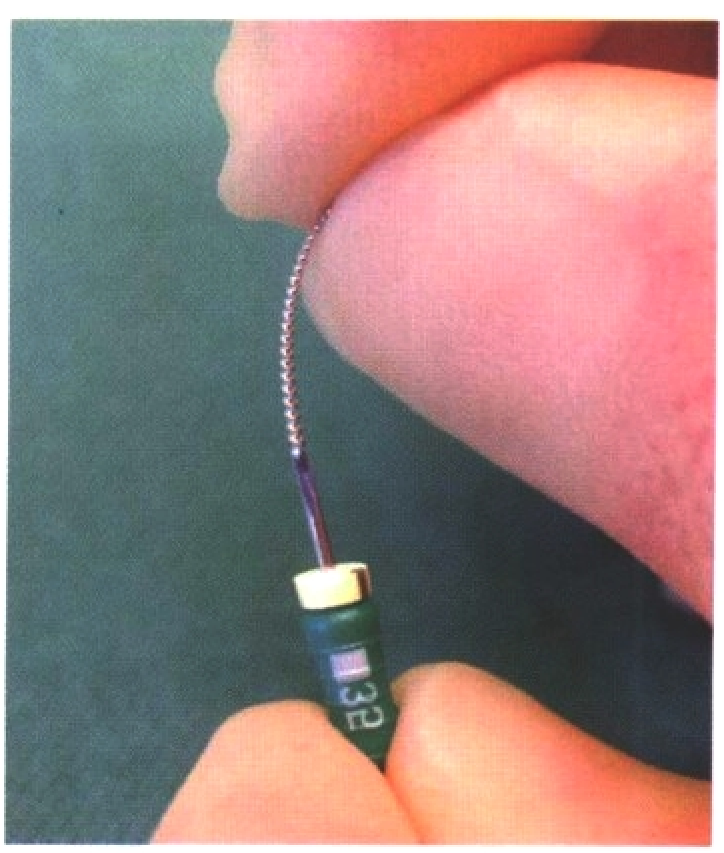




图 4–13a　为保持无菌，用消毒过的止血钳弯曲锉针（左）。这样处理的锉针放入血琼脂平板培养基培养后无细菌生长（上）



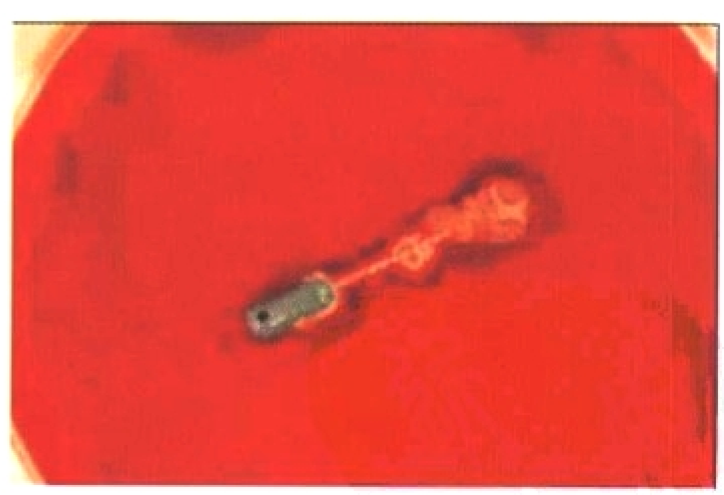


图 4–13b　如果用戴手套的手指弯曲锉针（左），培养后锉针周围有细菌生长（上）

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4. 将所有消毒过的器械（洁净）放在左边，所有用过的器械（污染）放在右边。右边所有用过的器械必须经过消毒后才能再放回左边继续使用（图 4–14）。

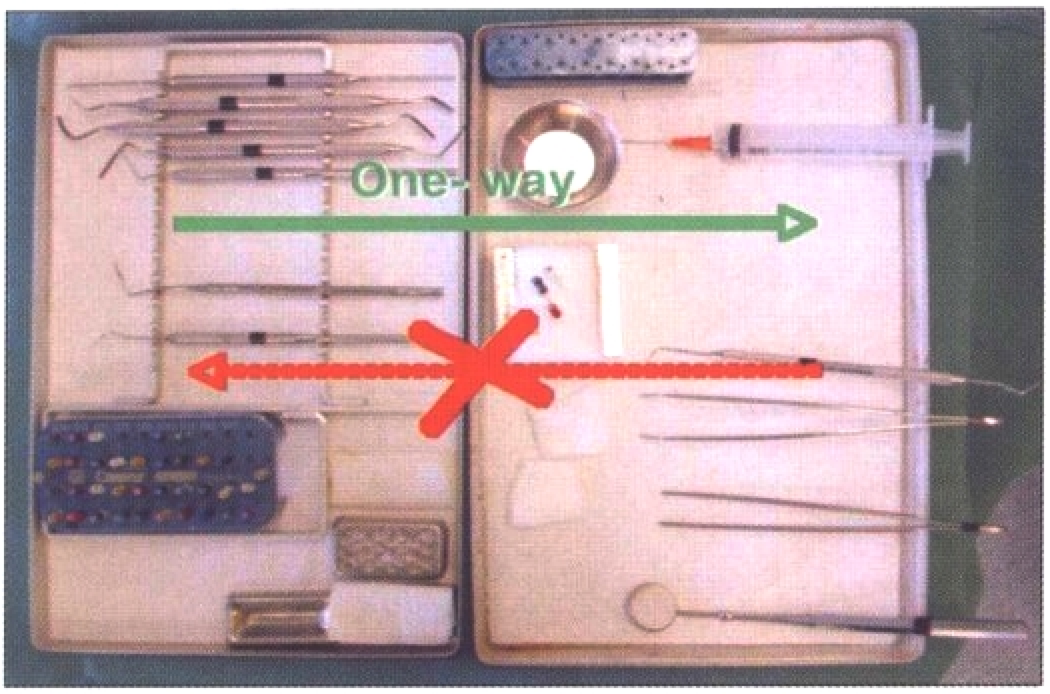


图 4–14 为了保持无菌，所有用过的器械（污染）放置在术盘的右边。必须将所有器械擦干净并消毒后才能放到左边（洁净）

工作长度

即使在今天，根管应被预备的长度仍是一个有争议的话题。大多数医生赞同根尖狭窄区或最窄点（又称小根尖孔，minor foramen）与根尖的位置并不一致（图 4–15）。因此，如果锉针到达 X 线根尖的话，锉针恐怕已经穿出了根尖孔（图 4–16）。组织学研究显示，狭窄区平均位于根尖冠方大约 0.5mm 的位置上。另外，有关根管治疗的转归研究结果断定，对于术前诊断为活髓的牙齿，根管预备及充填的最终位置位于 X 线根尖的冠方 1～2mm 时治疗结果最好。另一方面，对于诊断为牙髓坏死或根尖周炎的牙齿，根充到距 X 线根尖冠方 0.5～1mm 时的治疗效果最好（图 4–17）。几乎所有的研究都显示，无论患牙的诊断为何，过长充填的预后最差！为进行根管预备确立一个位于或短于小根尖孔的

工作长度对于根管充填也十分重要。通过在根尖部位形成一个阻隔，就可以对根管进行加压充填，使根充材料占据整个管腔。这样，充填材料就能够侧向移动，与根管的真实形状相一致（图4–18）。在没有根尖阻隔的情况下进行根充就好像充填近中–𬌗或远中–𬌗洞形时上成形片不用楔子一样，充填物会“泄漏”到牙周韧带中去，不但窝洞没有充实，还容易发生再感染。

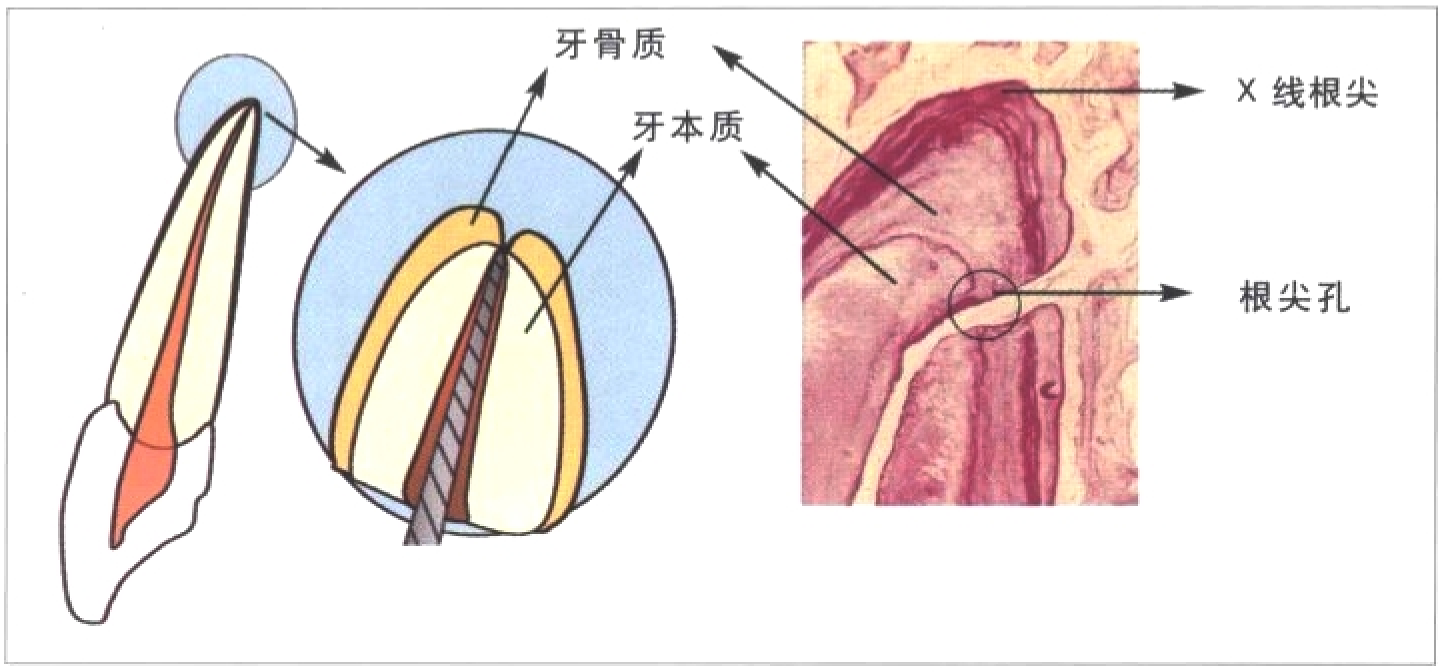


图4–15　前牙的近中面观。根尖区的“自然”狭窄处距X线根尖0.5～1.0mm

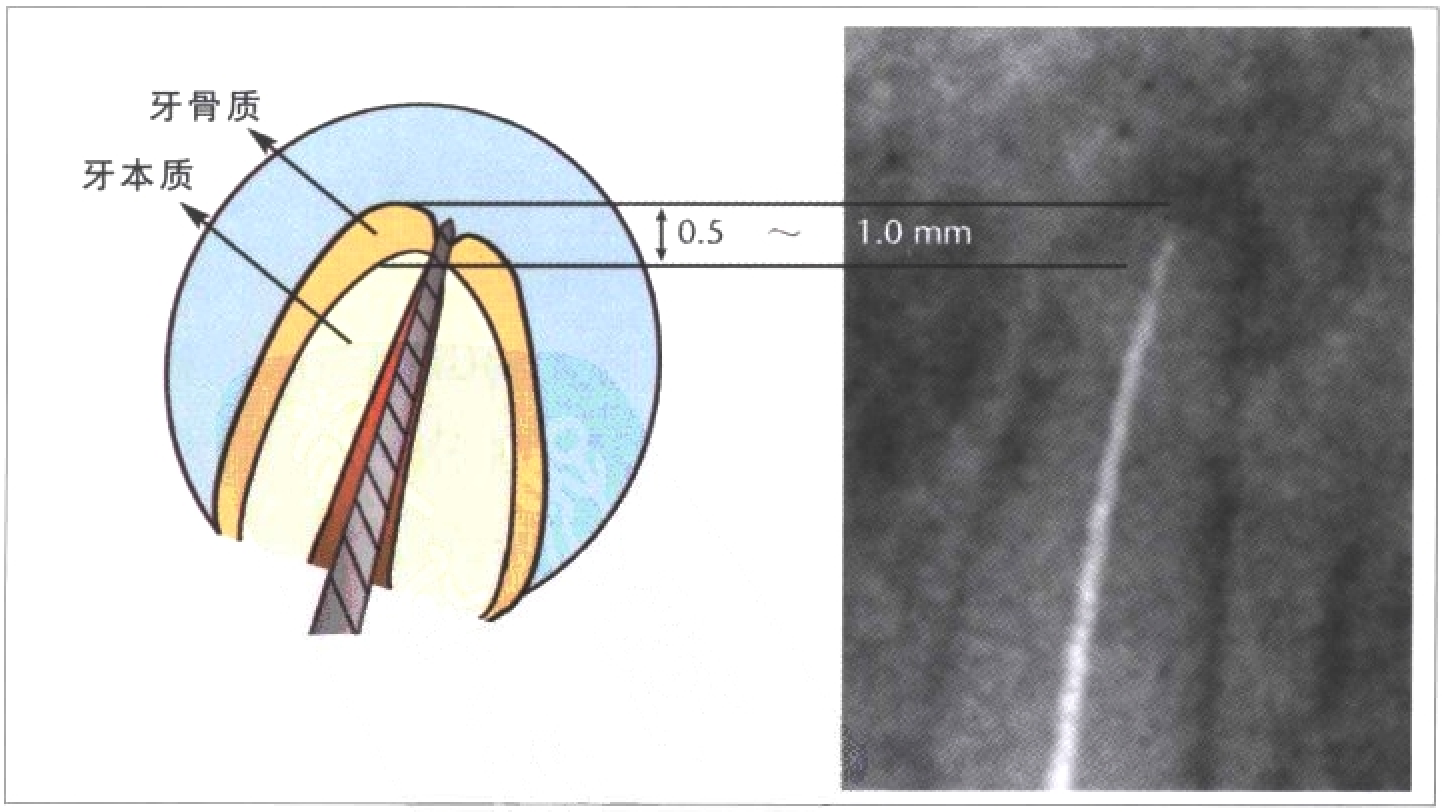


图4–16 前牙的近中面观。X线片显示锉针位于根尖顶的位置时，可能意味着锉针已穿出了根尖狭窄区

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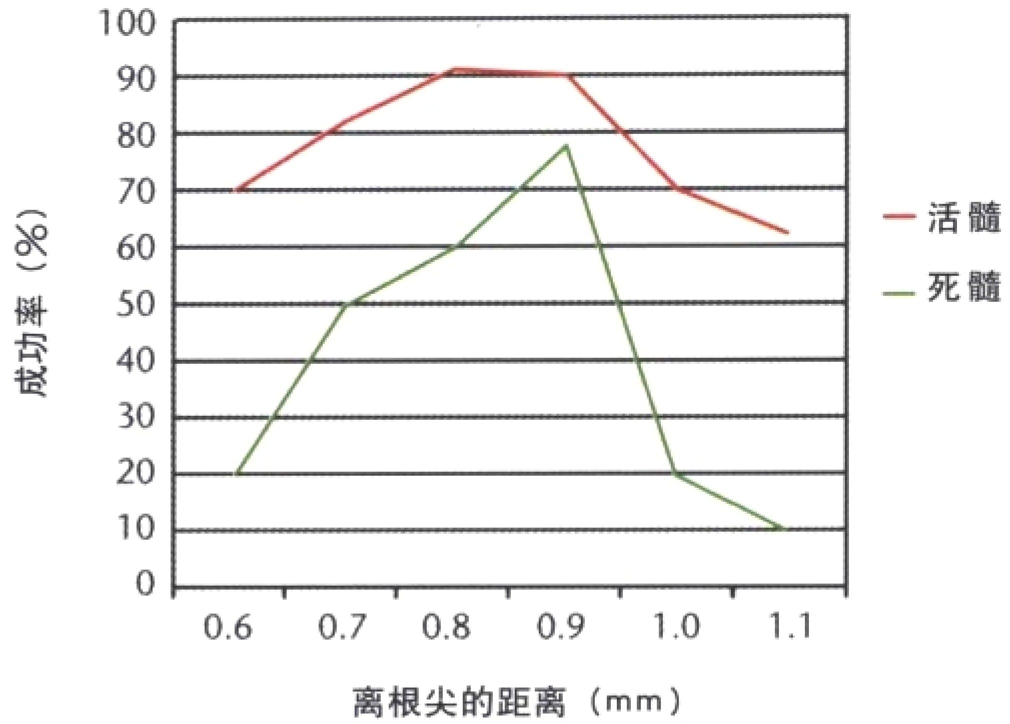
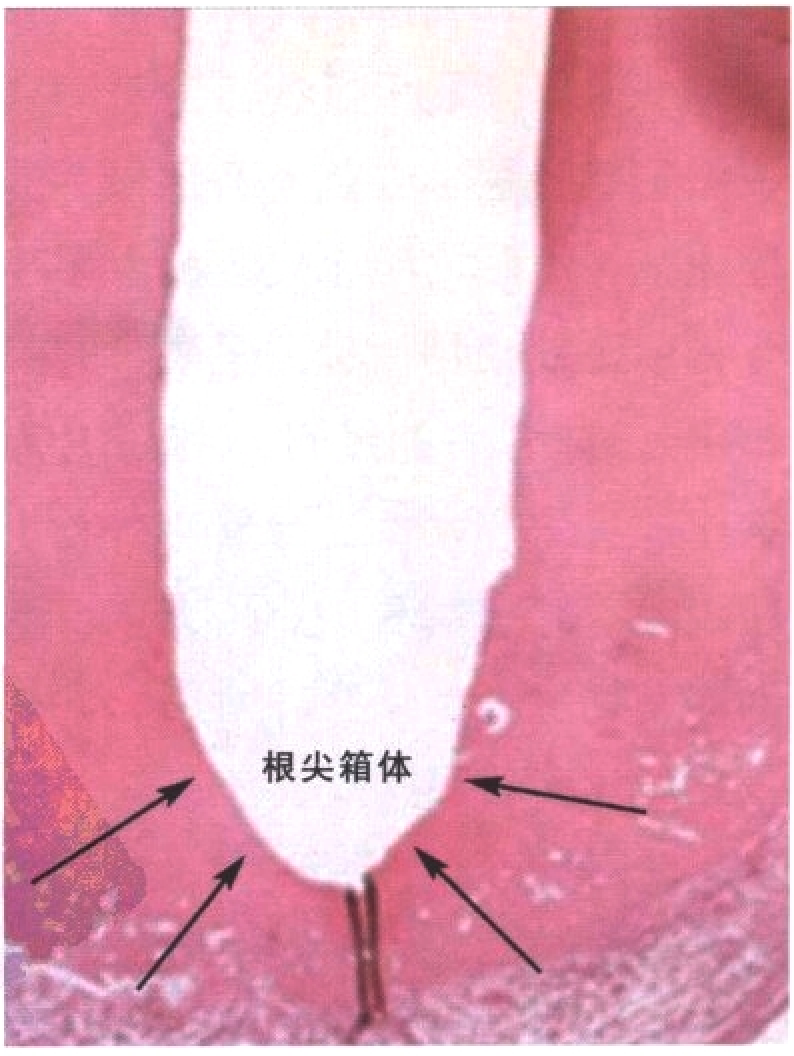


图 4-17　活髓牙和死髓牙根管治疗的成功率。在这两类牙齿中，都是充填的最终位置短于 X 线根尖时治疗的成功率最高。特别是在死髓牙中，过长充填时成功率降低

图 4-18 根尖区牙本质内的箱状形态起到型模的作用，有利于取得最佳的充填效果



在这一阶段的治疗中，由于随着根管冠2/3段的预备，根管的长度会有略微的改变，没有必要知道精确的工作长度。因而，在此阶段只需确立一初步工作长度即可，一般为X线长度减去1mm。如果医生确信术前X线牙片是平行投照的结果（见前面所述的预估工作长度），甚至可以不需要工作长度X线片，待预备完根管的冠2/3后再投照精确的长度片。

根管预备

去除所有的龋损和发生渗漏的修复体后，制备直线通路，接着上橡皮障并确保其封闭严密，并用表面消毒剂对术区进行无菌消毒，此时即可开始根管预备。以上步骤是微生物控制中最重要的方面，操作中一般与抗菌冲洗液一起使用。

投照工作长度X线片之前，用10号不锈钢挫探寻根管。必须清楚的是，只能用镍钛锉沿已明确的根管进行预备，而不能用其找出根管。医生应首先确定根管的走向，制备出到达根尖孔的开放通路，然后才能比较容易地用镍钛锉沿这一通路展开预备。探寻根管时要使用比较“坚硬”的不锈钢锉（8号，10号，15号或20号）。依作者的经验，用10号锉探寻根管工作长度最适宜。对锉的顶尖2～3mm进行预弯（图4–19），这样，轻微旋钮锉柄就可使锉尖探寻根管的不同方向。通过这种类似“上发条”的旋钮动作，锉针就会“空转滑落”入根管。如果遇到阻挡，可稍微回抽锉针，转动锉柄改变锉尖的指向，再进针继续探寻根管（图4–20）。疏通不畅的根管时，医生必须极其耐心细致，如果试图强力使锉针穿过阻碍，就会形成极难逾越的台阶（图4–21）。

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如果锉针到达预估工作长度附近后仍感松缓，就应换用大一号的不锈钢锉针深入到根尖孔，直到锉针不能轻易地达到预估工作长度为止。此刻扩大“自然”根管的腔径，可减少其后为使根尖1/3的管径小于根管的其他部位所需使用镍钛锉的数目（见第3章，基本原则）。一旦锉针接近工作长度，就可运用逐步深入技术和旋转器械预备根管。

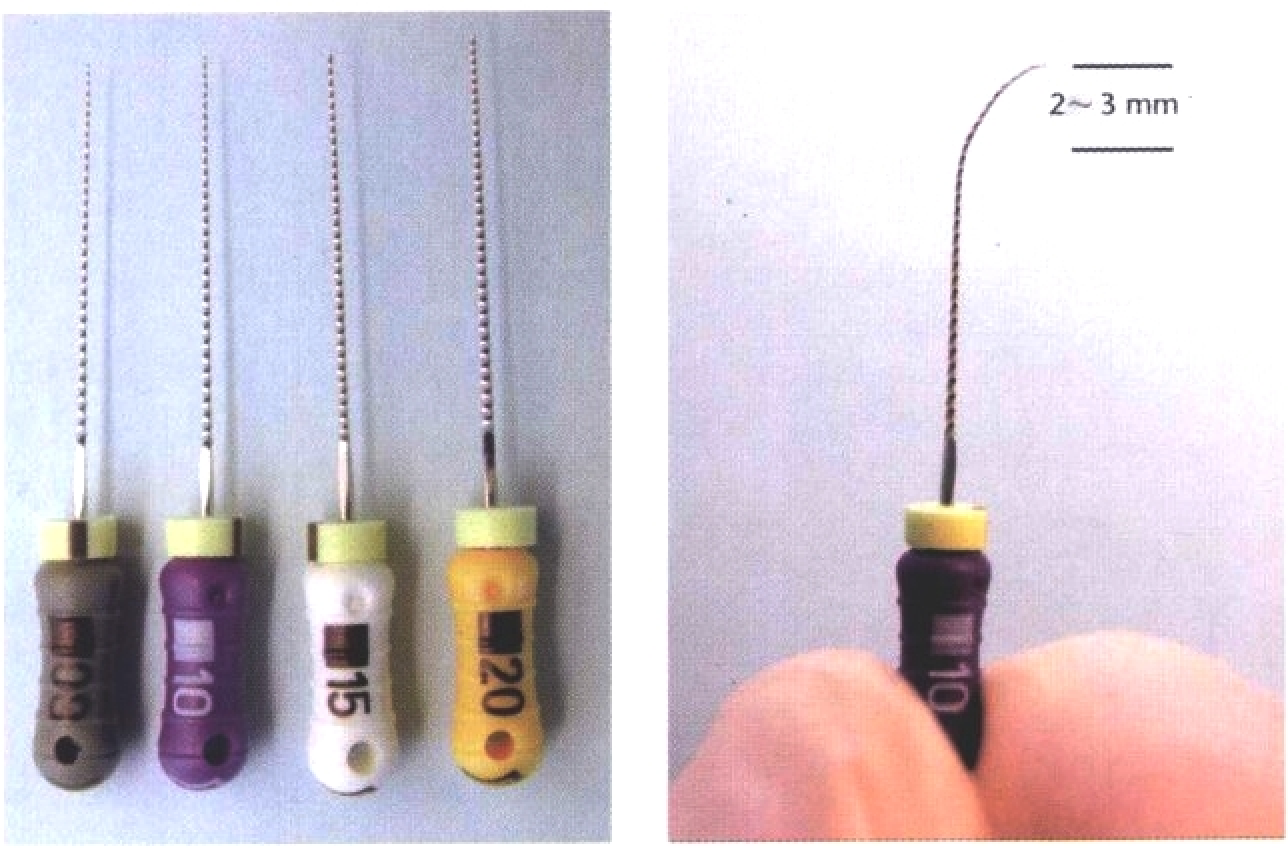


图4－19 对“坚硬”的不锈钢锉进行预弯。 术者通过类似“上发条”的旋钮动作使锉针滑入管腔

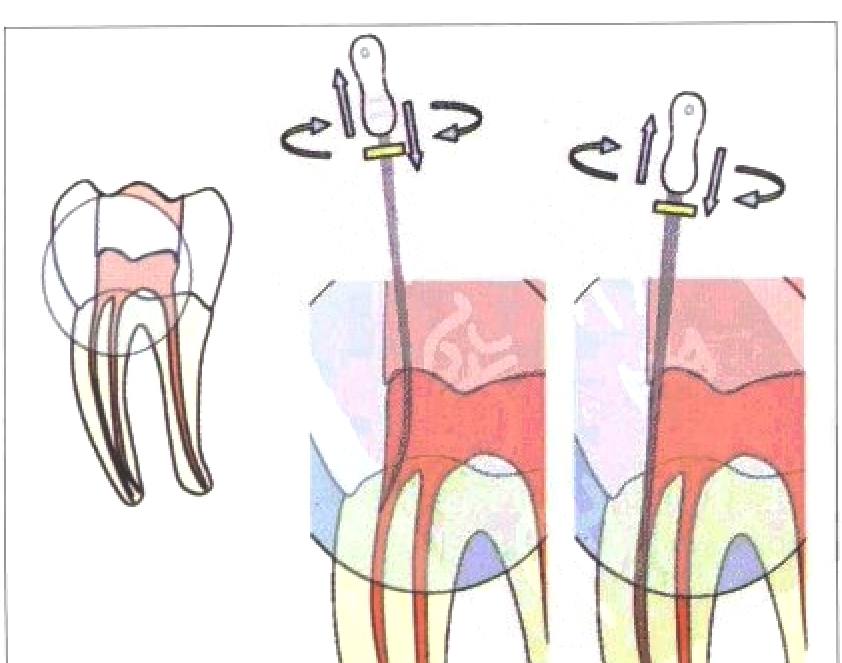


图4－20 通过类似手表上发条的旋钮动作使预弯的锉针滑入管腔

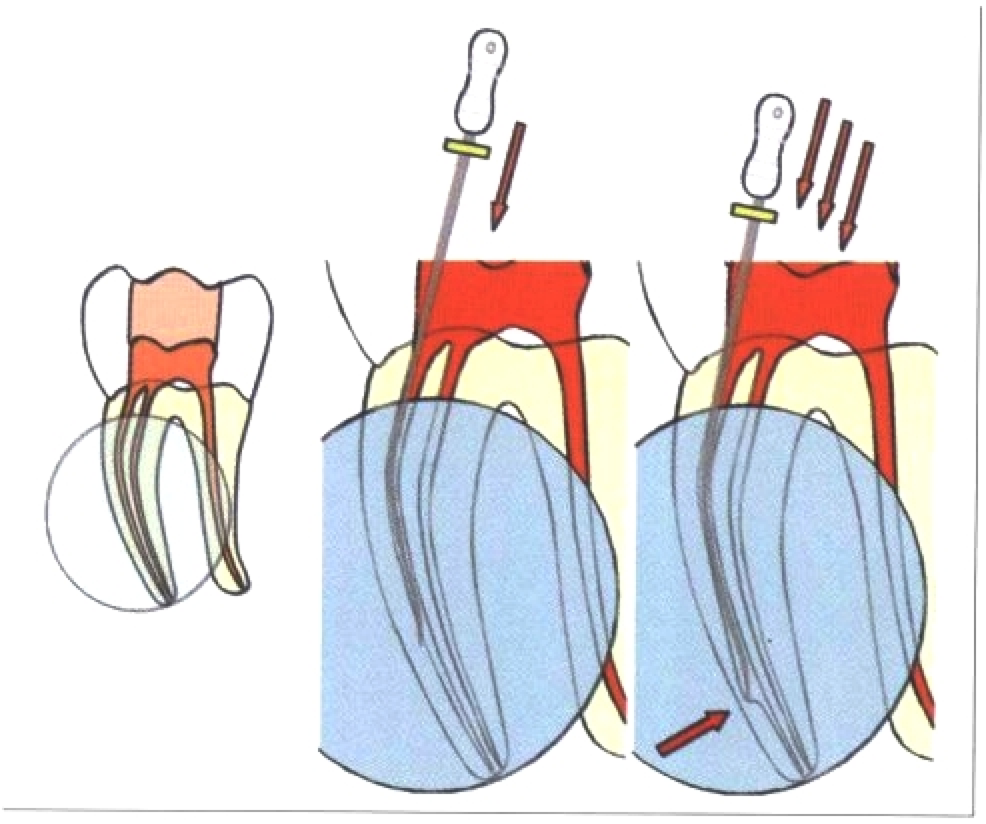


图4–21a 旁路逾越根管阻碍。遇到阻碍时应避免用力使锉针继续深入，不然会在管壁上形成台阶

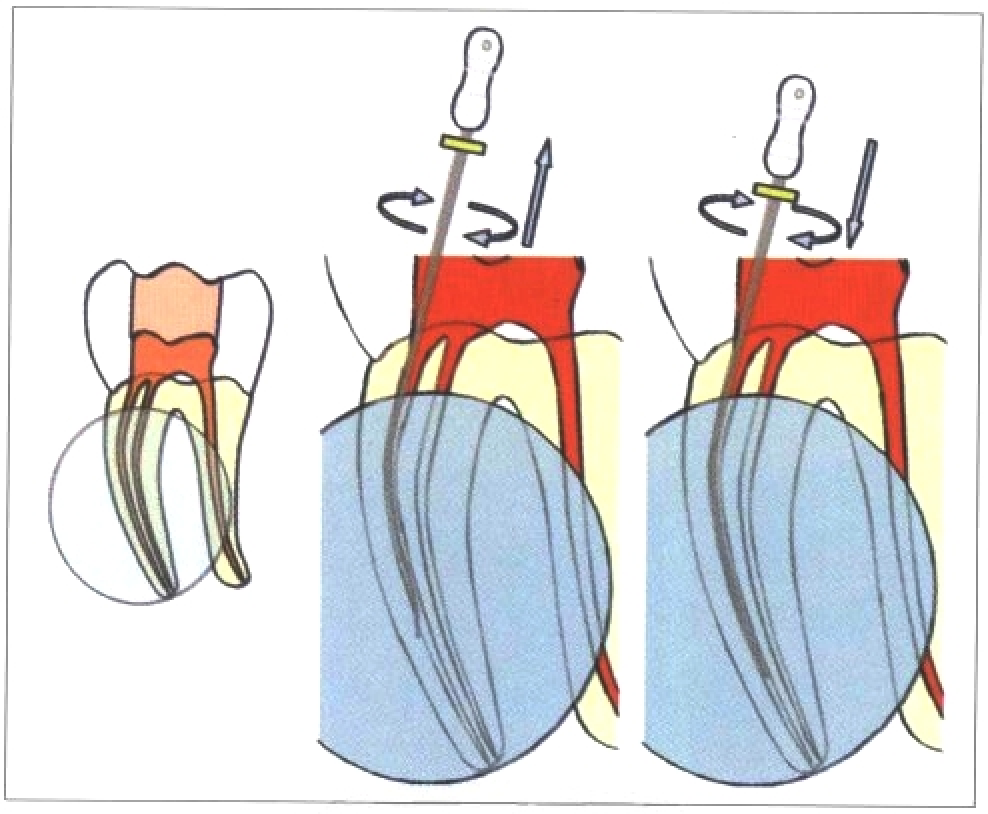


图4–21b 旁路逾越根管阻碍。可稍微回抽已预弯的锉针，像给手表上发条一样转动锉柄改变锉尖的指向，再轻轻推动锉针越过阻碍

使用不锈钢锉的改良逐步后退技术

如前所述，运用由小号到大号的锉针自根尖至冠方预备根管的方法很难将根管扩大到所需的尺寸，使根管得到充分的清理。使用这种技术时，管腔的根尖部分容易被牙本质碎屑阻塞，妨碍大号的锉针进入到根尖1/3，甚至会引导锉针偏离根管的曲度，造

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成根管直化、侧穿（分叉区穿孔）、根尖侧穿等。为防止这些问题发生，对逐步后退技术进行了以下改进：

1．用不锈钢锉预备至工作长度，预备到25号为止（25号锉极其松缓时可扩到30号）。其间对根管进行充分的荡洗。

2．将锉针加大一号，用30号锉（或35号锉）预备根管至短于工作长度1mm的位置，间以充分荡洗。

3．重复这一过程直至用40号锉针预备根管至工作长度冠方4mm的位置。

4．用更大一号的锉针上下方向反复磨锉管壁，扩大根管工作长度冠方4mm以上部分的管径。

5．用30号锉回探至工作长度，此时，由于前面的预备结果，锉针在进入工作长度的过程中应不会遇到阻力。

6．预备根尖1/3段，直至其管径达到符合生物学要求的程度（图4–22和图4–23）。

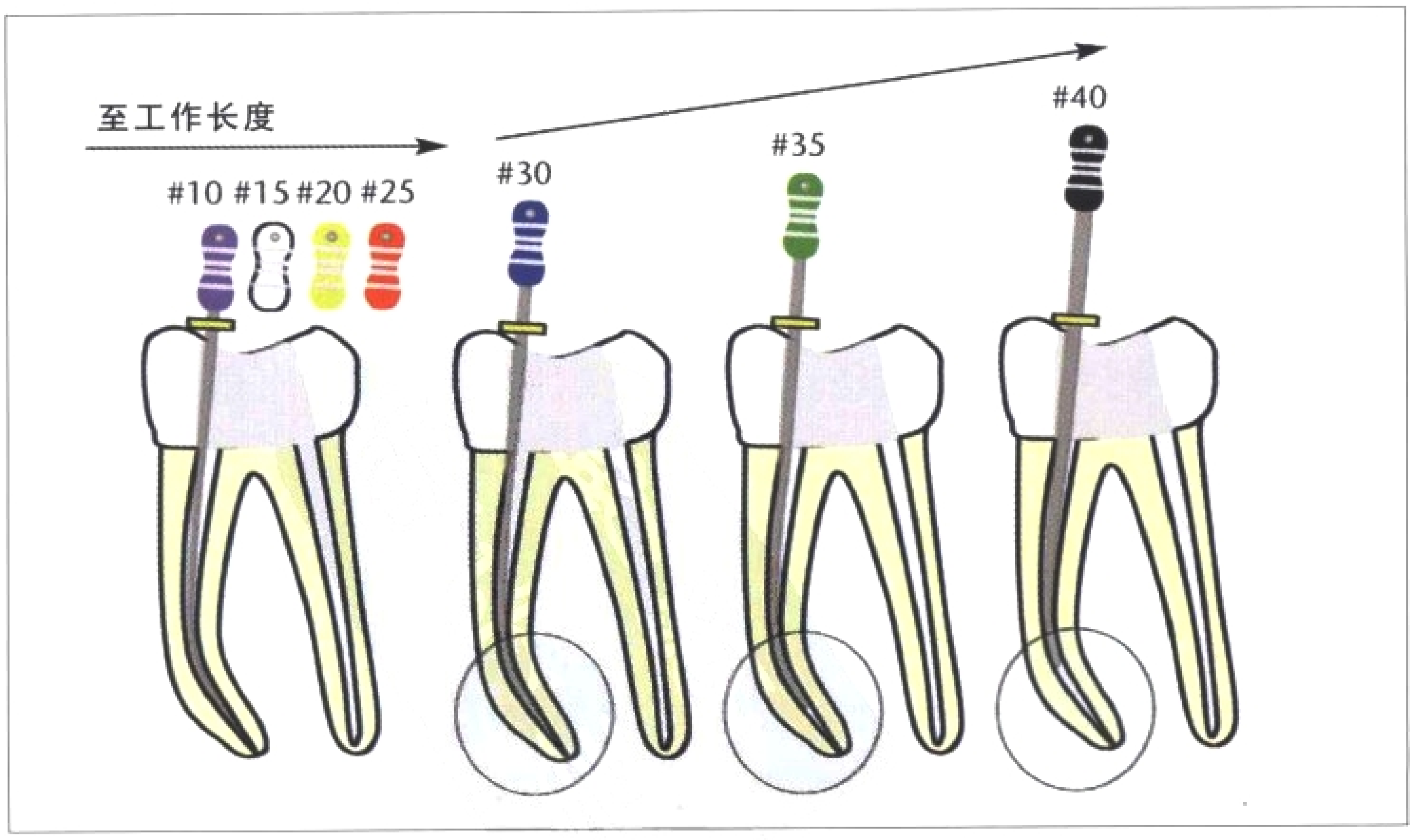


图4–22 改良逐步后退技术。第一步：用传统的逐步后退技术扩大根管冠2/3的管径

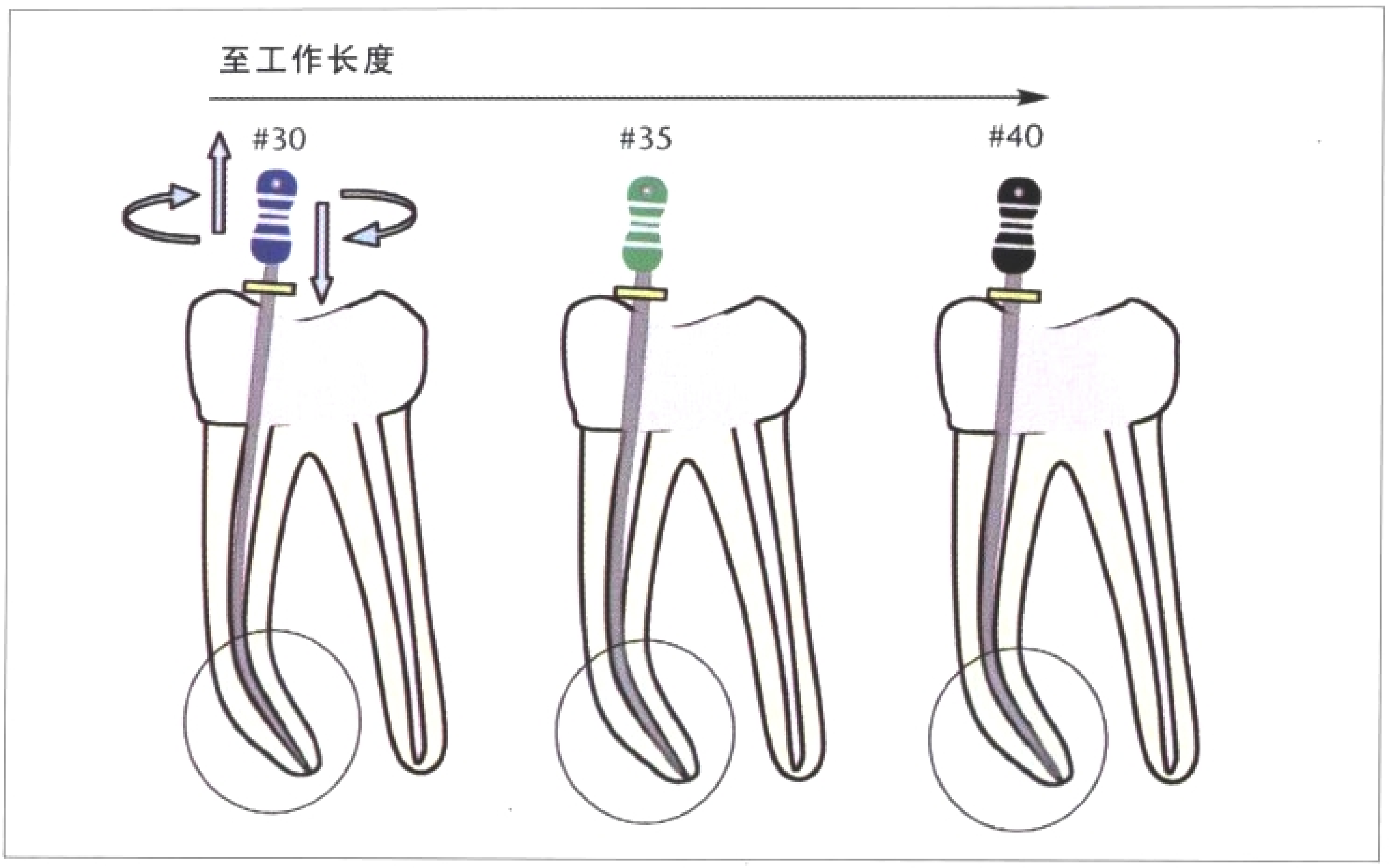


图 4-23 改良逐步后退技术。第二步：将根管的根尖 1/3 部分预备到符合生物学要求的尺寸，且不造成牙本质碎屑栓堵

使用镍钛锉的逐步深入技术

如前所述，作者认为与不锈钢锉相比，旋转镍钛器械有明显的优点，所有的医生都应认真考虑使用这一系统。确实，单单使用不锈钢器械进行根管预备的话题只应成为历史术语被提及。镍钛锉极度柔韧，几乎可以向任何方位弯曲。一经移出根管，锉针就会弹回原有的形状（直立）。但值得注意的是，虽然镍钛锉富有弹性，但趋于拉直根管。镍钛锉的柔韧性（使其与根管的形状一致）及其变直的内在趋向（导致根管拉直）之间矛盾作用的结局取决于牙本质抵御切削的能力与锉针切割效能之间对抗的结果。医生一定要清楚各种镍钛锉的切割效能，因为这决定了这些器械应被如何使用。

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“低效”切割器械

大多数早期镍钛旋转锉都可归为“低效”器械（图4–24），这些锉只是刨平管壁而非深入切割牙本质。但这种明显的弱点可通过配合使用转速为150～2；000 rpm的手机得以补偿。使用这类器械几乎不会造成根管直化，非常适合没有使用镍钛锉经验的医生。应用时惟一可能发生的意外是断针，但没有拉直根管的危险。

随着医生使用这类锉的信心不断增加，可尝试使用切割能力更强的器械。近来，推出了新一类的镍钛锉，其特征为具有类似不锈钢锉针的锐角切刃（图4–25和图4–26）。这种锐角切刃使新型器械切割牙本质的效能较前一代锉大大提高。当然，与前面提到的低效镍钛器械相比，其优势在于只需使用较少的几根锉针就能够更加迅速地完成预备。这类器械的不利之处是其较强的克服牙本质阻力的能力，这会增加术者拉直根管的风险。因而，明了这两类镍钛锉的不同点以及正在使用的锉针的类型极其重要。无论使用哪一类型，都不能使锉停留在根管内一个位置上旋转。锉针在前进或由根尖后退时拉直根管的风险不大，但旋转的锉针在根管中的一个位置上持续停留时，肯定会造成根管直化。

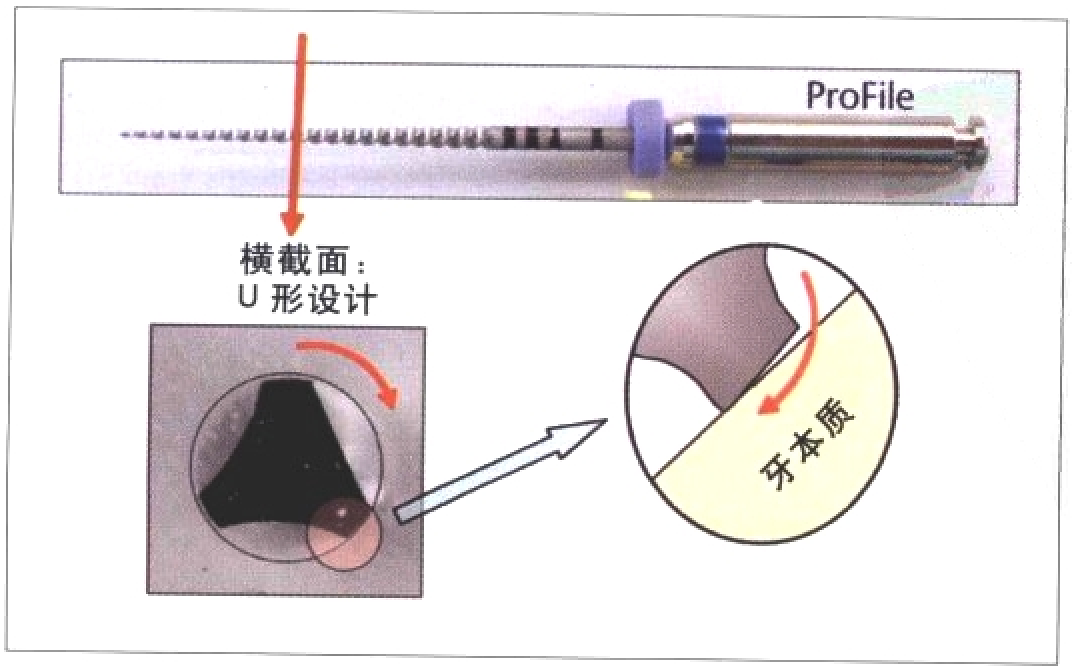


图4–24　ProFile锉的切割效能低下，原因在于工作方式为刨平作用。其低效性确保了根管不会被直化

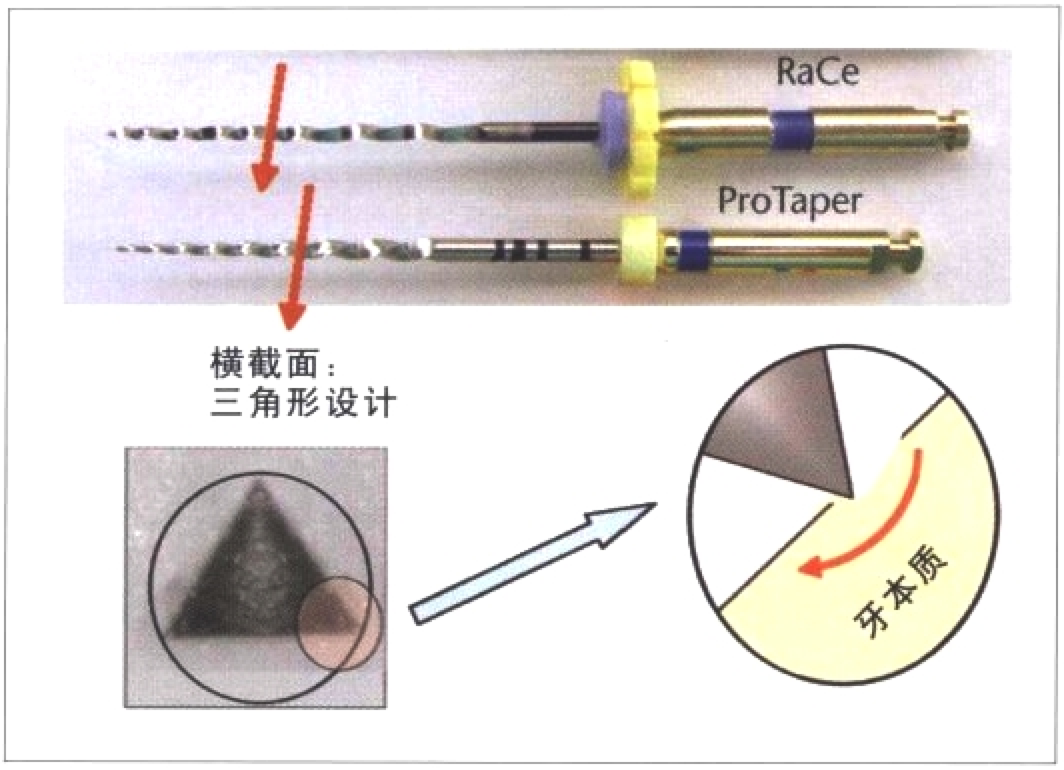


图 4–25　Pro Taper 和 RaCe 锉由于具有锐角切刃，其切割效能较高

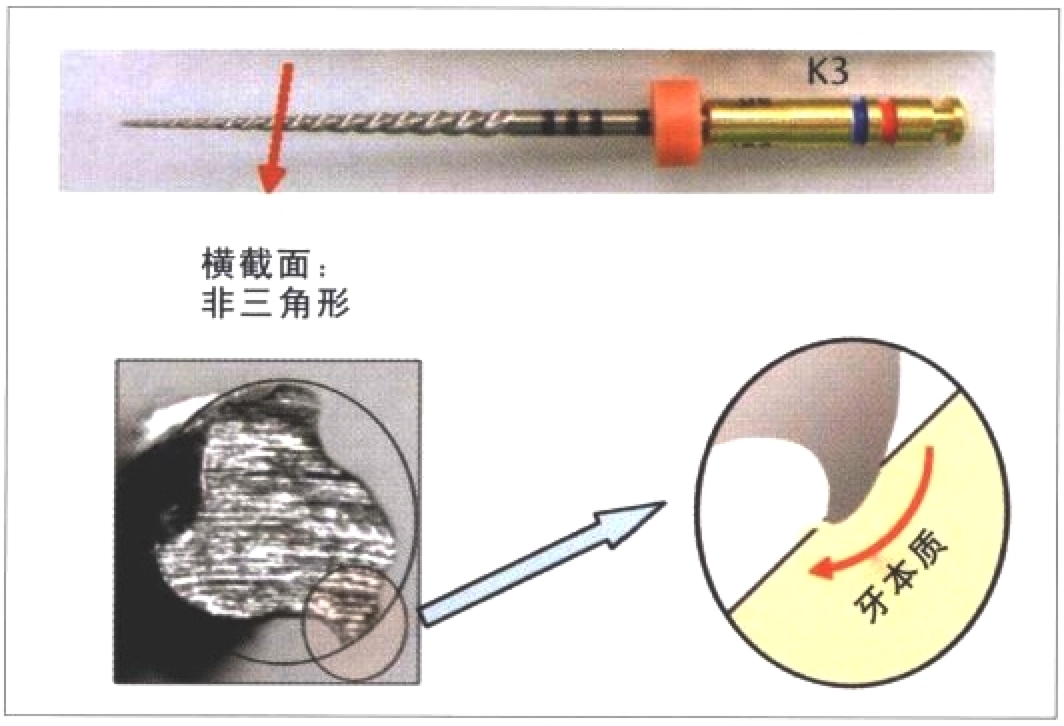


图 4–26　K3 锉也是一种高效能切割器械

目前，商品化的镍钛锉系统有多种。作者认为，只要使用得当，这些器械都要优于不锈钢锉。以下是使用镍钛锉进行根管预备的几条基本准则。预备分两步进行：首先用逐步深入技术（Crown–down technique）预备根管的冠 1/3 部分，然后另行扩大根尖 1/3。

1．建立到达根管口的直线通路（图 4–19）。

2．用不锈钢锉探寻根管（图 4–20）。

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3. 依次用尖径逐渐减小（但不小于25号）的0.10，0.08，0.06锥度锉针预备根管的冠1/3部分（例如工作长度减去8mm的位置）（图4–27）。

4. 依次用尖径逐渐减小（但不小于25号）的0.06，0.04锥度锉针预备根管的中1/3部分（例如工作长度减去4mm）（图4–28）。

预备完根管的冠2/3后，接着预备根尖1/3部分。由于这一阶段中每一锉针都要预备到同一长度，确定准确工作长度十分必要。准确工作长度对根管治疗的成功至关重要，基于这一原因，作者极力建议预备完根管的冠2/3后再来确定准确工作长度，因为

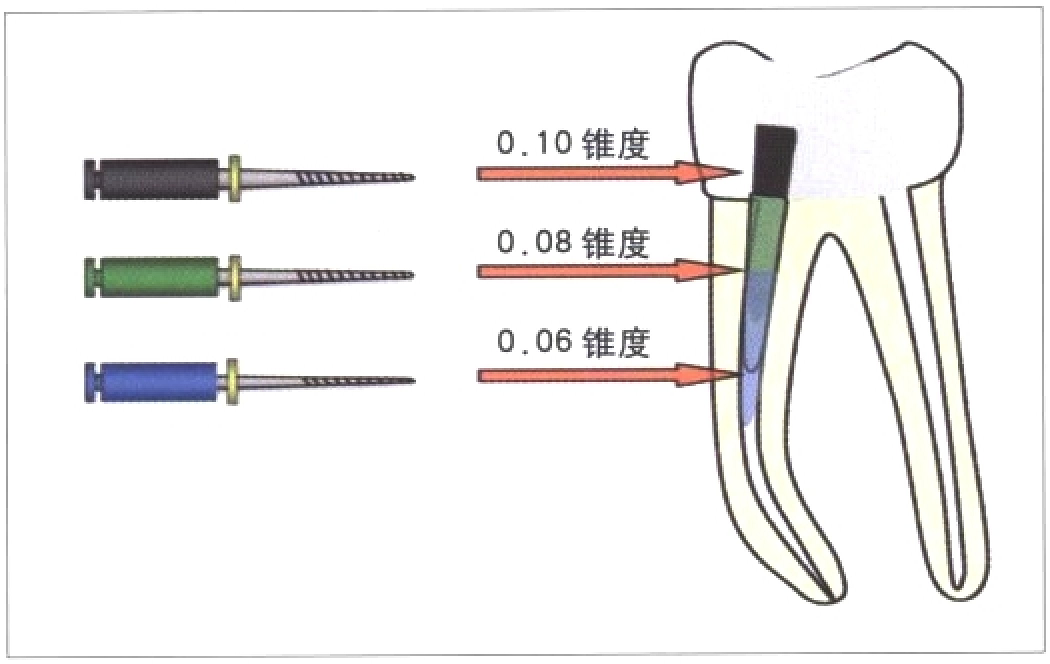


图4–27 逐步深入技术。依次用尖径逐渐减小（在某些系统中锥度也逐渐减小）的锉针预备根管的冠1/3

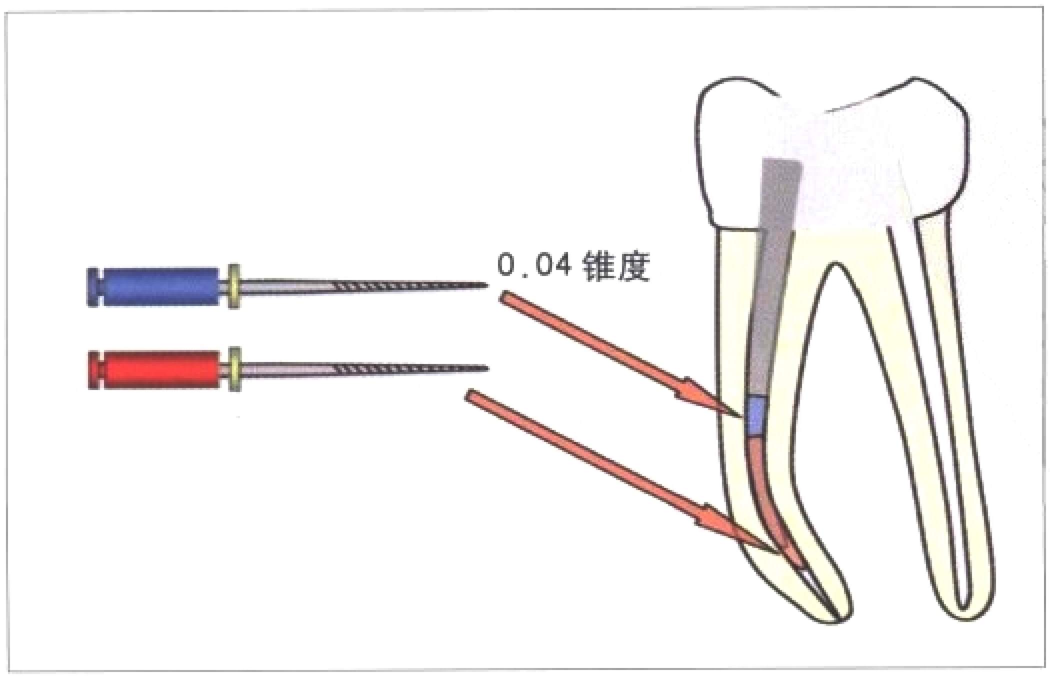


图4–28 逐步深入技术。用锥度相同但尖径逐渐减小的锉针继续根管预备

第一阶段的根管预备能够在一定程度上造成根管直化或变短，从而导致根管长度改变。

有多种方法可用来确定准确工作长度。结合使用这些方法能够明显提高测得正确预备长度的机会。

* 手指感觉。由于冠2/3已得到充分预备，可以用小号锉针探估小根尖孔的大小和位置。将一10号锉针探入到预估工作长度；如果锉针能够滑过这一长度，说明锉针太细。换用大一号的锉重复这一过程，直到锉尖在预估工作长度附近遇阻“卡死”为止，多数情况下，这一长度即是准确工作长度。

* 根管长度测量仪（图4–29至图4–31）。商品化的根管长度测量仪多种多样，其中多数比较准确，能够在存在一定水分的情况下使用。作者认为，这种仪器是非常有用的工具，可用于大部分的病例。由于能够反映锉针接近或离开小根尖孔的动作，这种仪器是目前最准确的根管长度指示器。

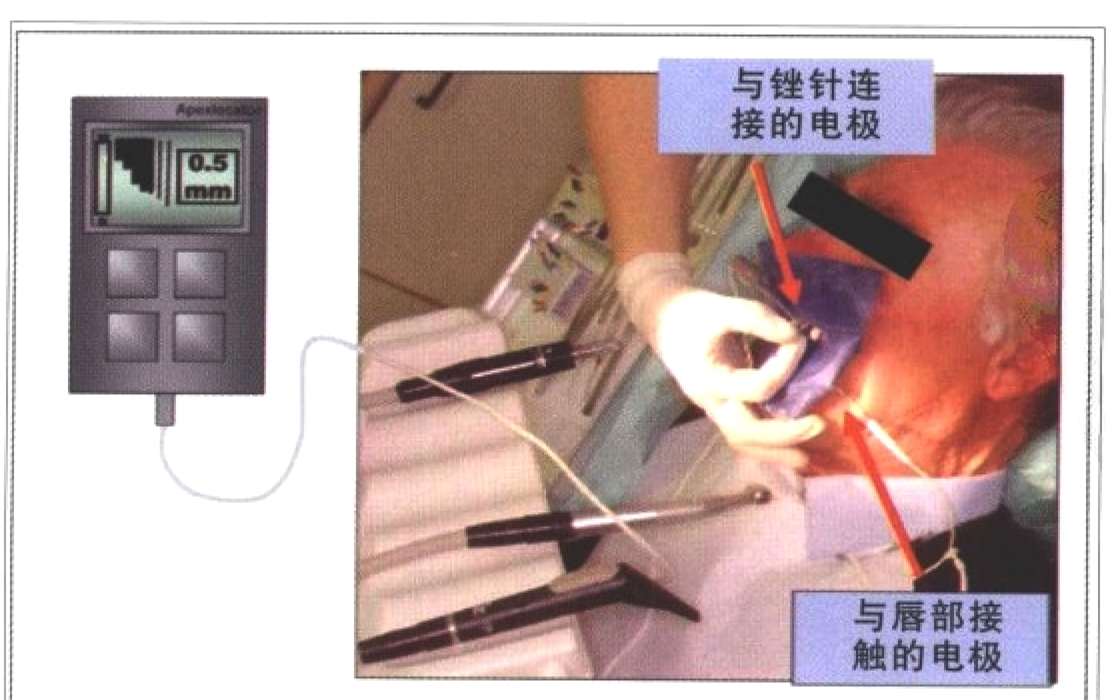


图4–29 使用根管长度测量仪是目前定位根管狭窄区最准确的方法之一。电极的一端附靠在唇部，另一端与锉针连接形成回路

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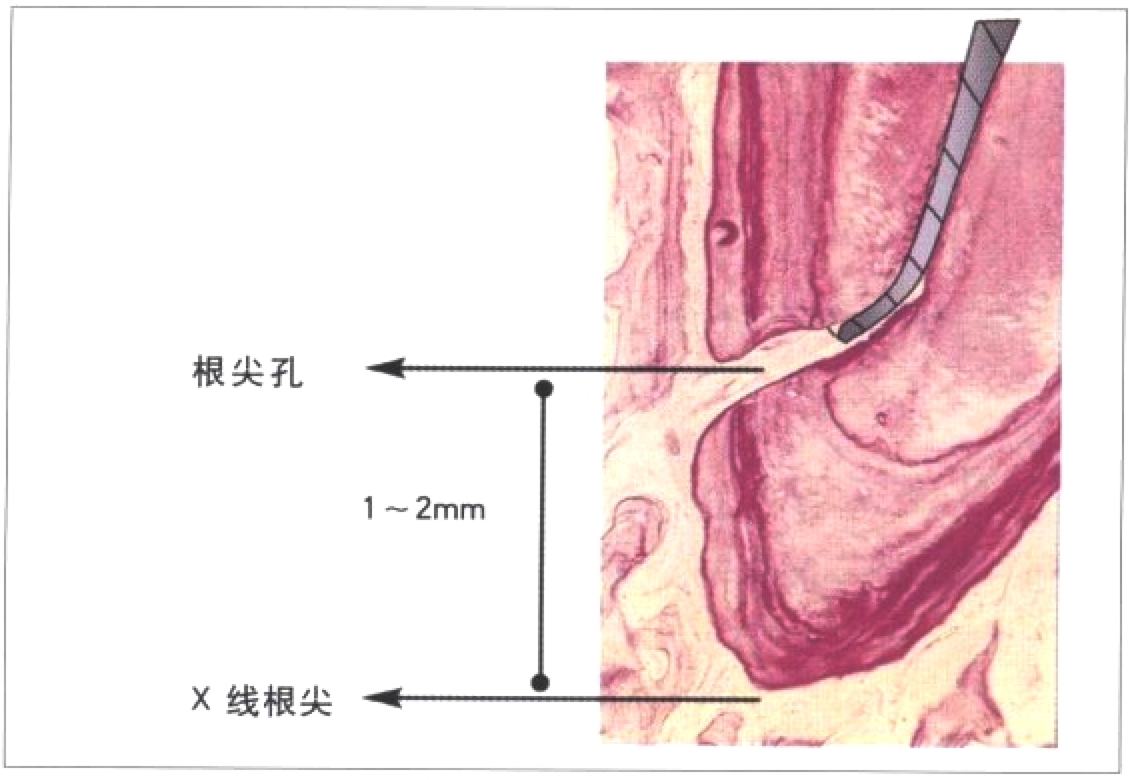


图 4—30 根管狭窄区的位置一般短于 X 线根尖

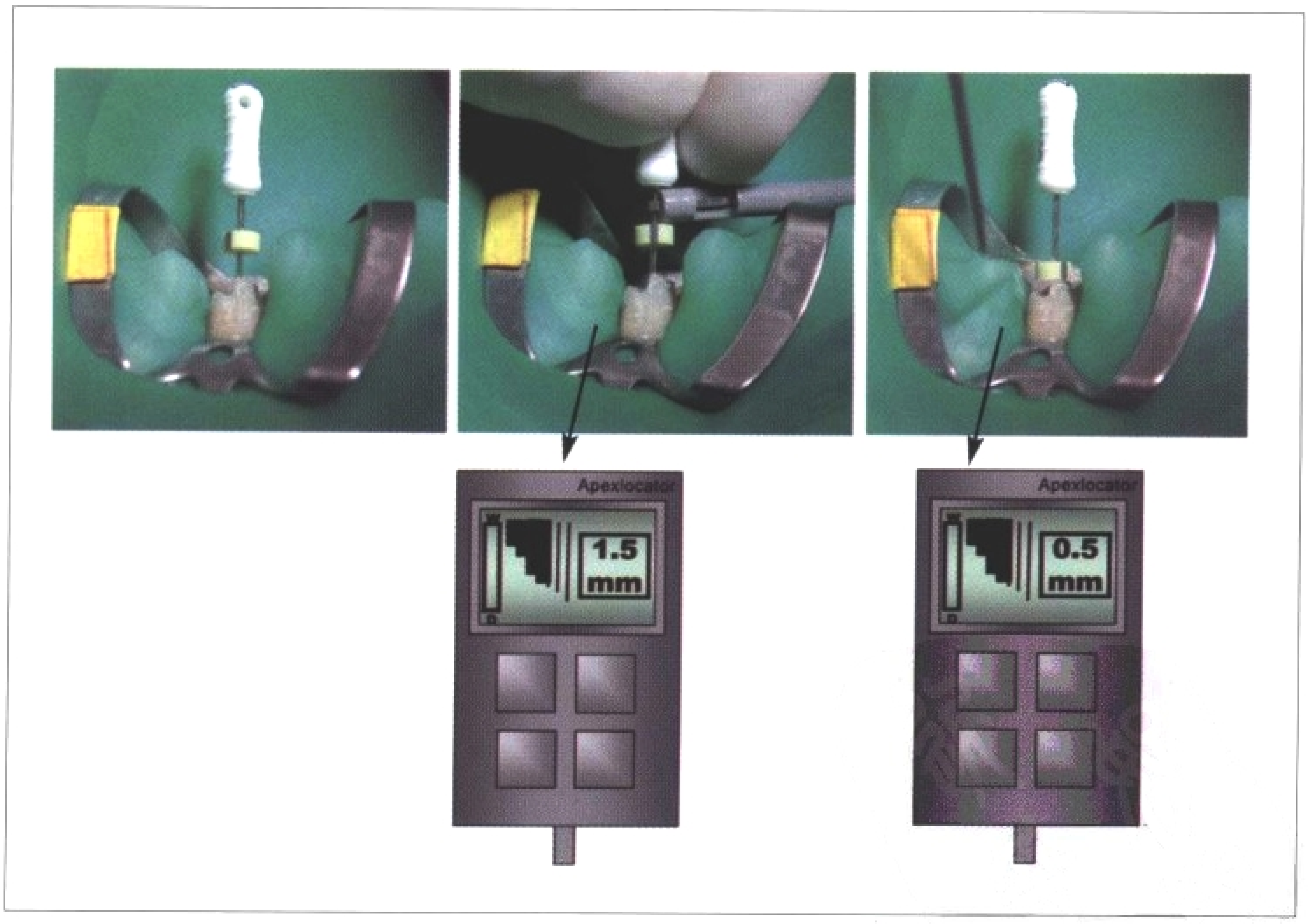


图 4—31 根管长度测量仪在长度达到距根尖狭窄大约 1.5mm 时开始指示。大多数情况下，当测量仪显示距根尖狭窄 0.5mm 时，即可认为达到了所需的长度。如果锉针在两个长度位置（1.5mm 和 0.5mm）之间的移动变化能够在测量仪的读数上被相应地反映出来，就应认为仪器是准确的

＊ X线片。投照X线片是确定工作长度最常用的手段。照相时使用平行投照装置（见预估工作长度篇），并结合在根管内插针指示（图4—32）。但医生必须清楚，X线测得的工作长度只是一种估计长度，必须结合手指感觉和根管长度测量仪确认这一工作长度的准确性。

一旦准确工作长度得以确定，就开始用锥度为0.02或0.04的ISO 15～80号锉针依次预备根管，将其扩大到有利于高效清理根管的适宜尺寸（图4—33）。

＊ 手持15号及其以上型号的锉针依次深入管腔，找出不能到达准确工作长度的锉针，通常是20号或25号锉。

＊ 用依次增大的锉针预备根尖1/3，将其扩大到适宜的尺寸。

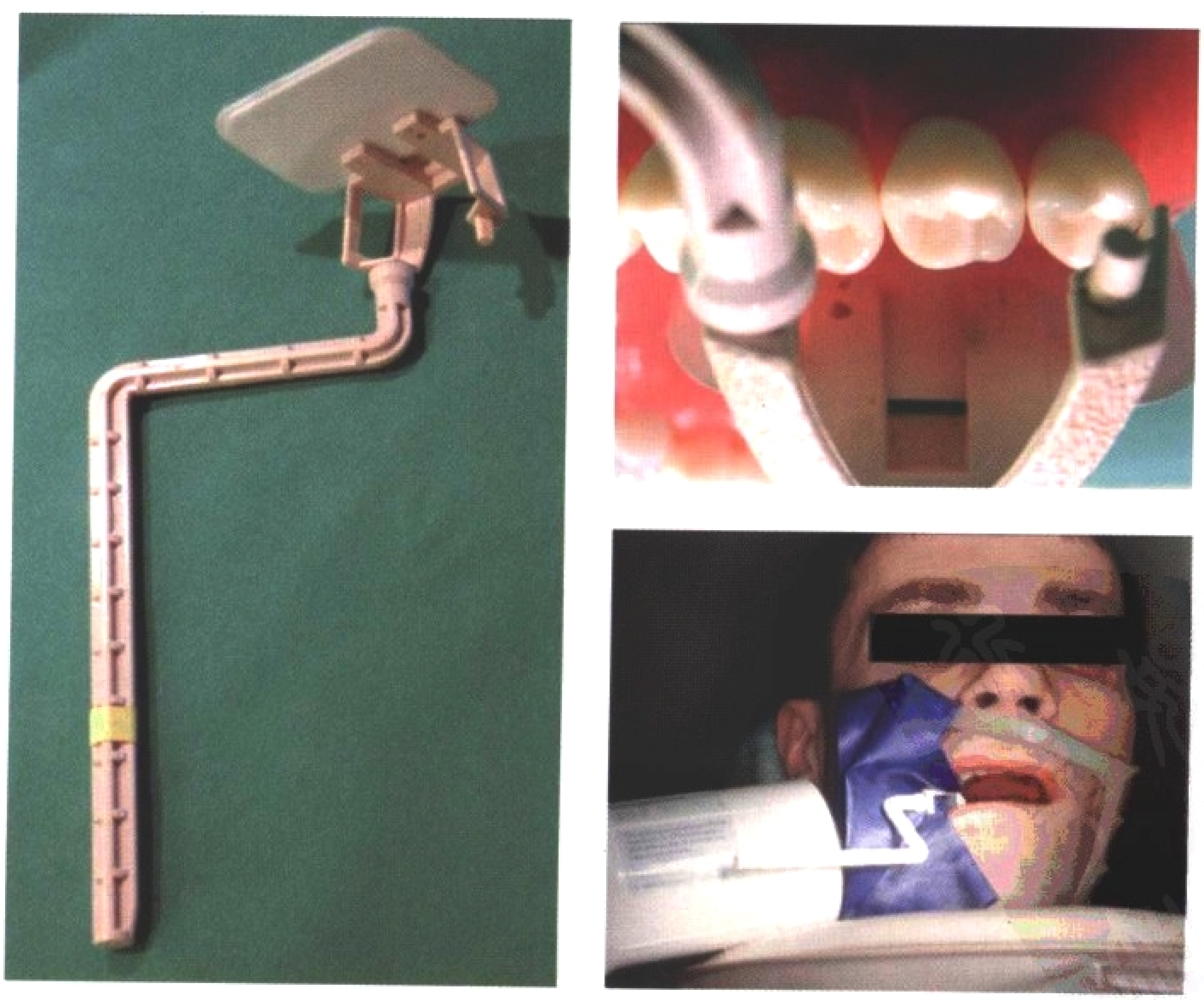


图4—32 使用平行投照装置能够摄取平行的插针X线片

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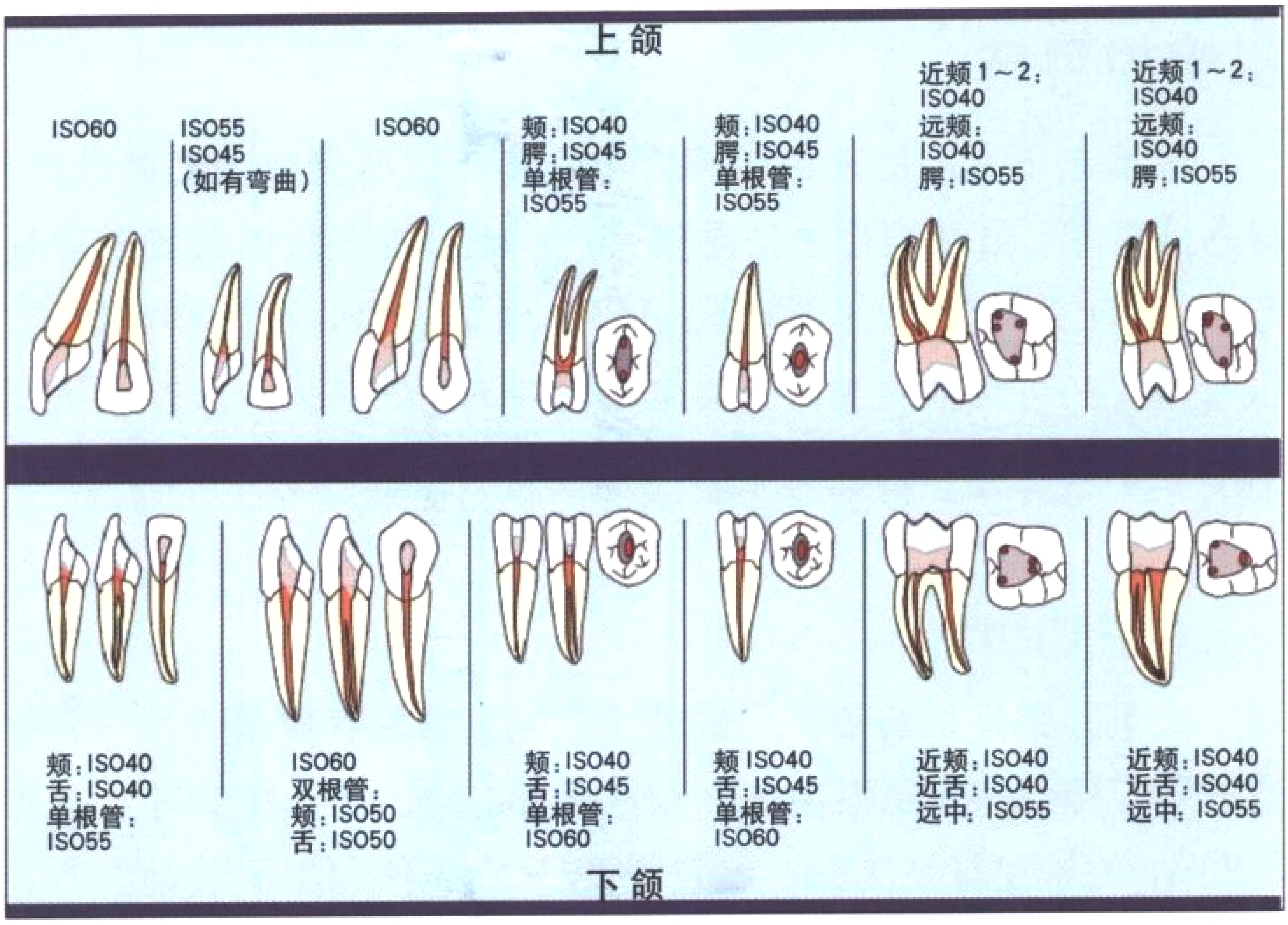


图 4－33a 根尖部最终应达到的最小尺寸

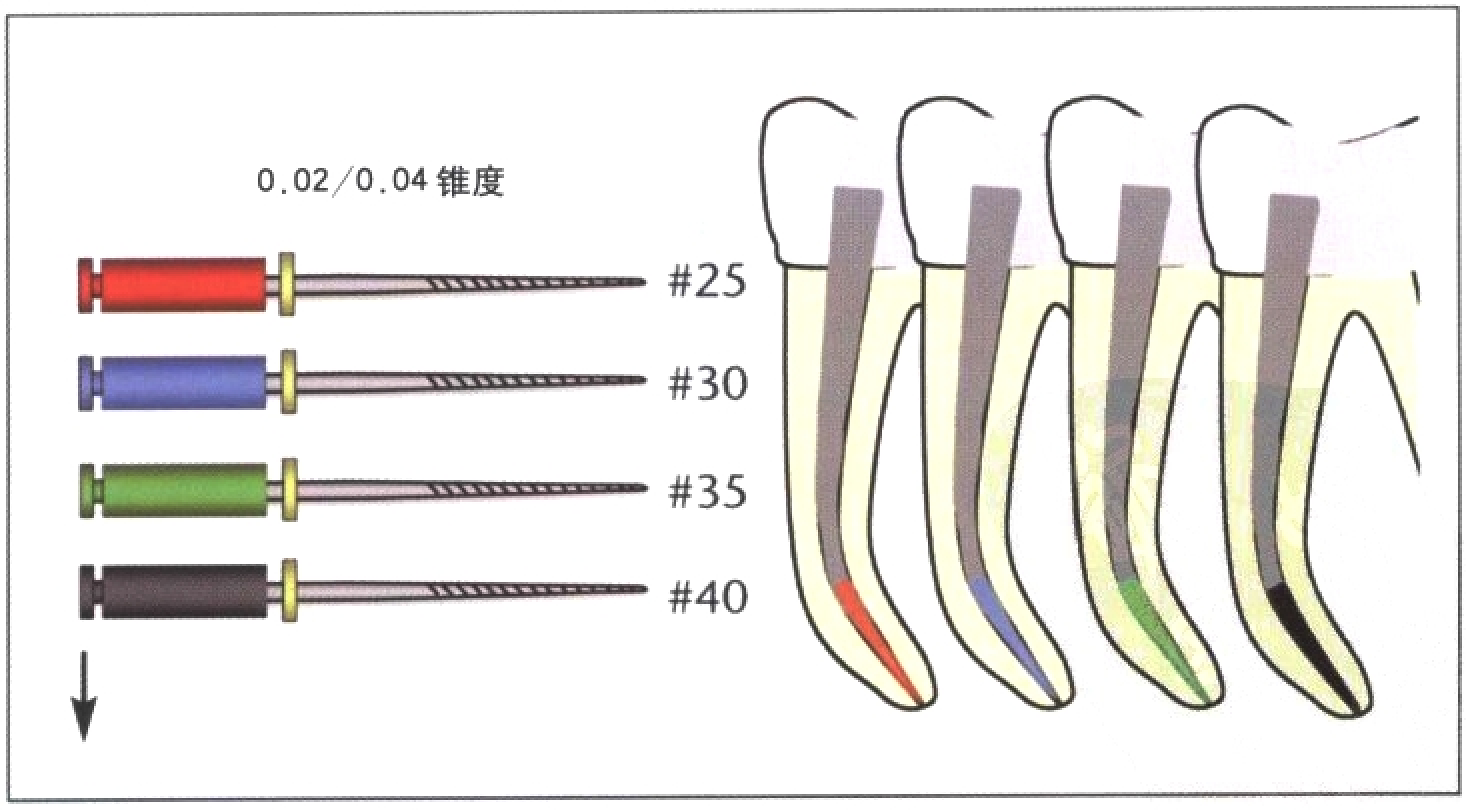


图 4－33b 逐步深入技术。预备完根管的冠 2/3 部分以后，再将根尖 1/3 部分序列扩大至符合生物学要求的尺寸

根管内用药

根管充填之前应该进行根管内用药，以尽量减少细菌数量，提高成功率。虽然根管预备是根管治疗细菌控制阶段最关键的环节，根管内用药对于取得稳定可靠的根管消毒效果也非常重要。根管内用药可分成两类：一类是根管冲洗药物；另一类是复诊间期封在根管中的药剂。

冲洗药物

次氯酸钠是目前最常用的冲洗药物。它既有抗菌作用，又能溶解坏死组织。次氯酸钠是一种家用漂白剂，用作根管冲洗剂时5.25% 的浓度被认为是“足效浓度”。临床使用次氯酸钠的方式多种多样，例如改变次氯酸钠的浓度（0.5%~5.25%）、温度、在根管内作用的时间等，但其差别并不明显。次氯酸钠的抗菌作用有一定的自限性，必须适时补充更新。每一根锉针预备后都用重新补充的0.5%浓度的次氯酸钠进行冲洗，其效果要好于将加热到60℃的浓度为5.25%的次氯酸钠在管腔中作用30min。次氯酸钠只是“被动”地清洗管腔时，其应用是非常安全的，但冲洗时一定不要加压使次氯酸钠强行冲出根尖孔，进入到根尖周组织。不然这种毒性药剂会造成根尖周组织坏死。因此，推注冲洗液前注射针头一定不要紧卡在根管中，针头在根管中应比较松缓。

乙二胺四乙酸（17% EDTA）是一种强效螯合剂，常与次氯酸钠结合使用以清除根管预备形成的沾污层（图4–34）。EDTA本身无抗菌功能，但通过清除沾污层，可以有效地消除依附于其上的细菌。除此之外，清除掉沾污层后，还有利于其他抗菌药剂杀死牙本质小管中的细菌。其使用方法与次氯酸钠基本相同，临床

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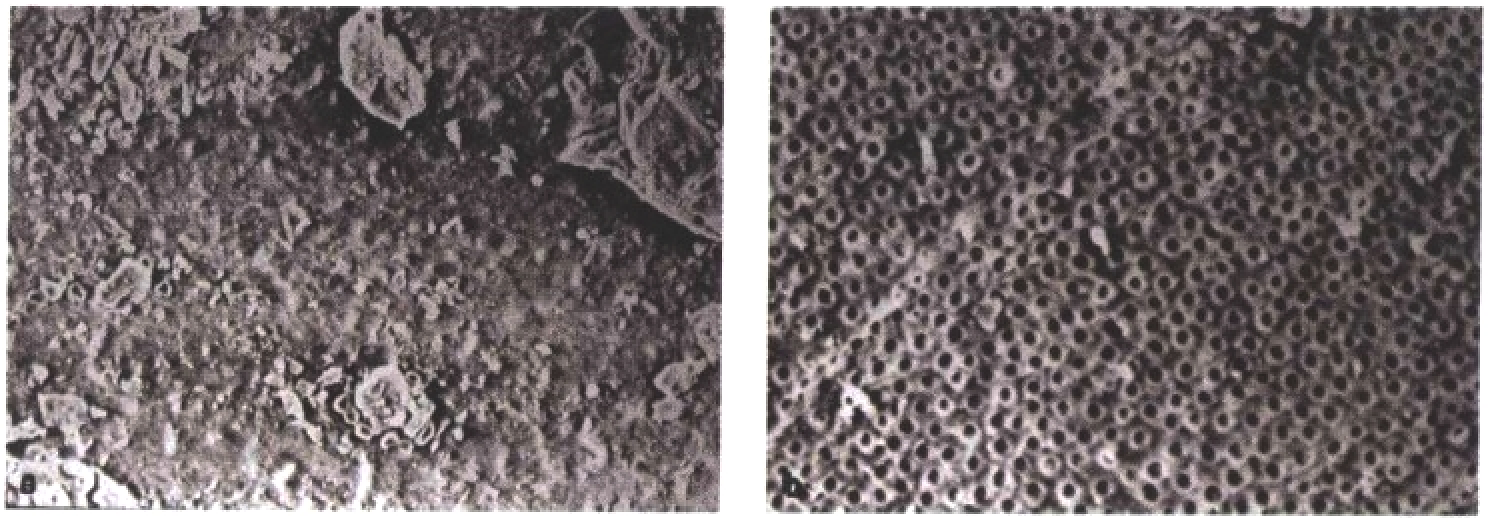


图 4-34 单纯使用次氯酸钠（a）不能清除根管壁上的玷污层。再用 17% EDTA（b）处理后，玷污层得以去除，显露出牙本质小管开口

应用时两者常交替使用。

另一种高效抗菌冲洗液是 2% 的氯己定液。其优点在于能够直接附着在管壁上，作用时间长达数天到数周。不过它不像次氯酸钠那样能够溶解坏死组织。氯己定也可与 EDTA 一起使用。

复诊间期用药

氢氧化钙作为复诊间期的根管内用药能减少根管中细菌的数量，使完成根冠充填修复后的成功率达到较高的水平。氢氧化钙应常规用于死髓牙及不能一次性完成预备和充填的活髓牙病例。

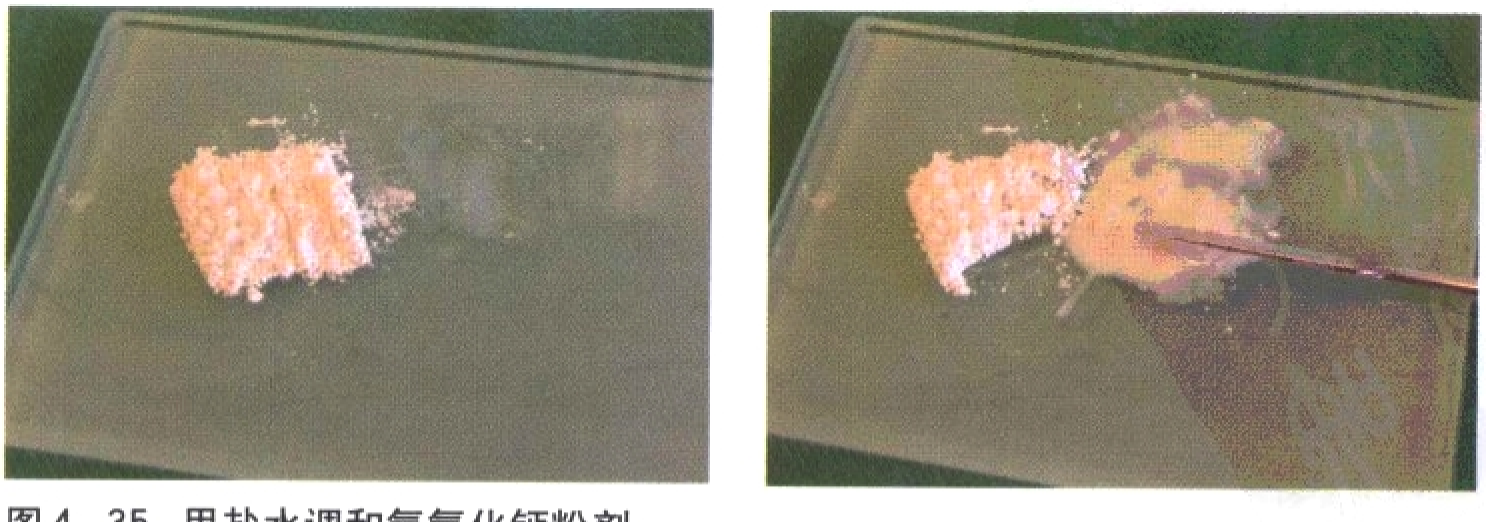


图 4-35 用盐水调和氢氧化钙粉剂

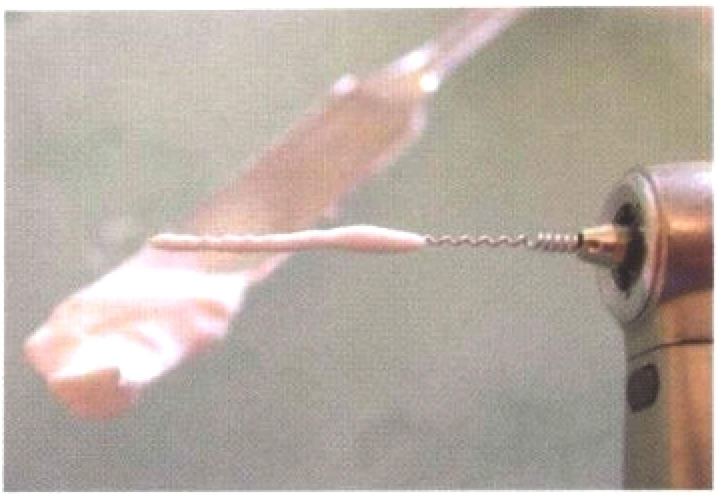



图 4–36　用螺旋输送器将调成糊状的氢氧化钙充入根管

使用时用无菌生理盐水或 2% 氯己定液将氢氧化钙粉调和成黏稠度类似牙膏的糊剂，用螺旋输送器充入根管，直至达到短于工作长度 2mm 的深度（图 4–35 和图 4–36）。也可使用商品化的软氢氧化钙制剂进行根管消毒。

根管充填

完成微生物控制阶段的工作后，必须对根管进行充填封闭。可考虑同步进行根管充填和在治疗牙上设置永久修复体。对牙冠部分的修复和对根管系统的充填同样重要，以营造一个有利于维持牙周长期健康的环境。在实现密封根管的过程中，根管充填的作用有以下三点。

* 将残留细菌密封在根管内，使其不能进入周围的牙周膜，迁延或导致疾病。
* 将组织液封闭在根管外，使其不能为根管中的细菌提供养分。
* 阻止唾液中的细菌通过冠方渗漏途径进入根管。

另外，用于根管充填的材料必须具备以下几种重要性能：使

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用方便；X线阻射；选择性毒性（对根管内细菌有毒性，正确使用时对根尖周组织无毒）；能够进行再治疗等。

牙胶尖和糊剂作为标准的根管充填材料已应用了多年。虽然牙胶尖具备理想根充材料的大部分特性，但在最主要的密封性能方面却表现较差。研究已经证实，牙胶尖不能有效地将所有的残留细菌密封在根管内。此外，另有研究显示，牙胶加根管糊剂抵御冠方渗漏的能力很差。实际上，总体研究的结果提示，冠方或上部充填对于根尖周组织的健康至关重要，反映出上部充填修复存在缺陷的情况下，牙胶加糊剂不能有效防止细菌渗入的弱点。牙胶尖加糊剂是牙髓病治疗过程中的薄弱环节。

最近开发出一种可以替代牙胶尖的粘结性根管充填系统Resilon（图4–37），这一系统由改性树脂尖组成（图4–38），具有许多与牙胶尖相同的特性，包括热塑性等。

Resilon树脂尖由完全聚合和交联的树脂构成，因而其大小尺寸比较稳定。遇热时树脂维持其交联性，但遇冷时收缩0.5%（牙胶则收缩3%～7%）。充填时先用自酸蚀首涂剂（图4–39）清除

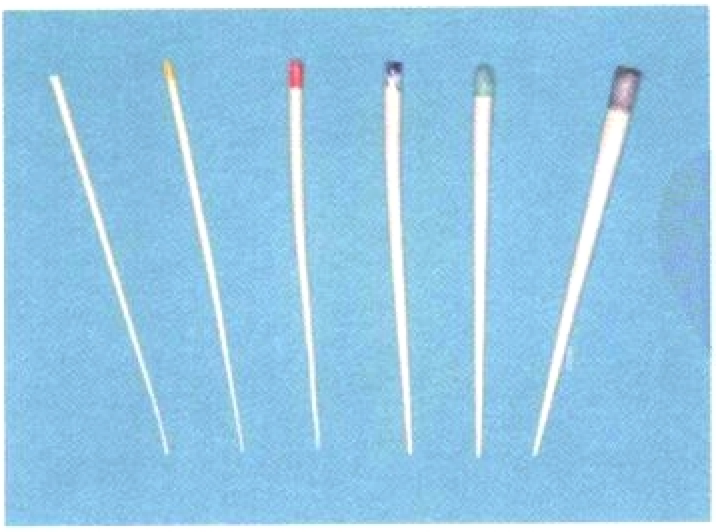




图4–37　Resilon　是一种改性树脂根充材料，其外观和使用方法与牙胶尖相似。另外，在这种树脂尖和糊剂中加入了填料，遇热或溶剂可以取出，能够进行再治疗

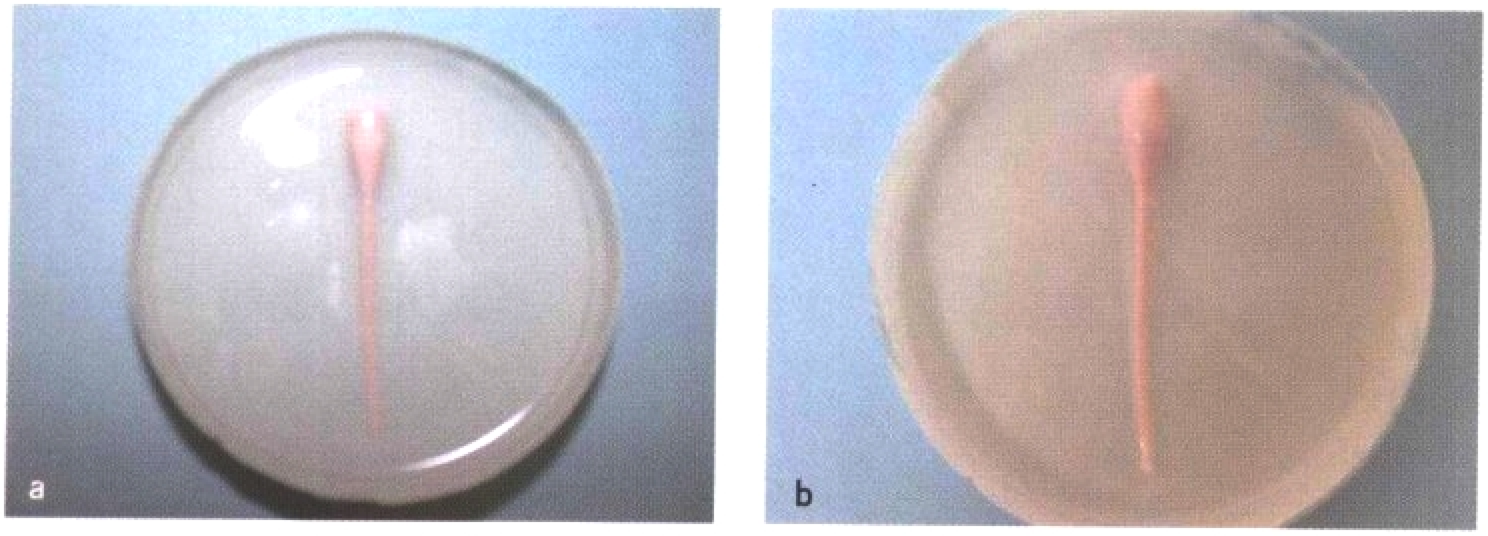


图 4–38　如有需要，可用加热和（或）用溶剂溶解的方法将 Resilon 树脂根充材料清理出根管。(a) Resilon　; (b)　Resilon 溶在氯仿中

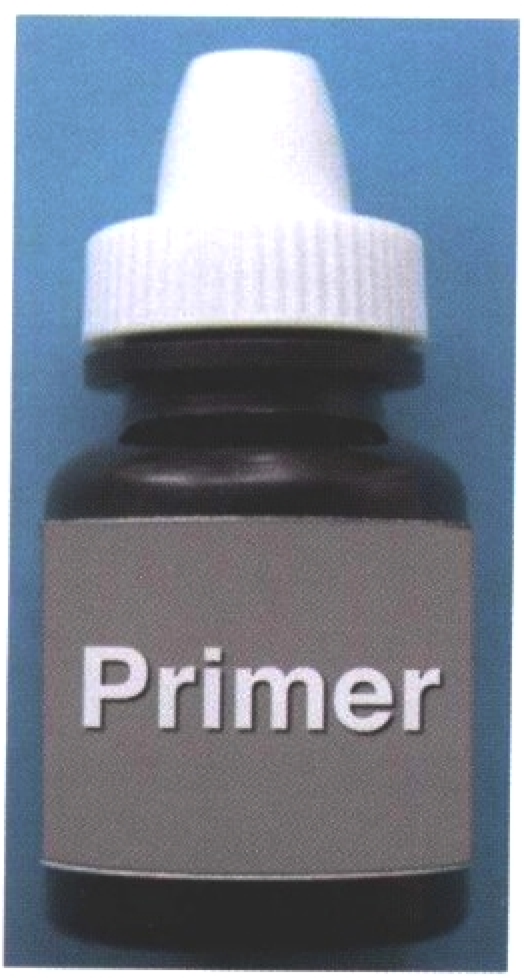
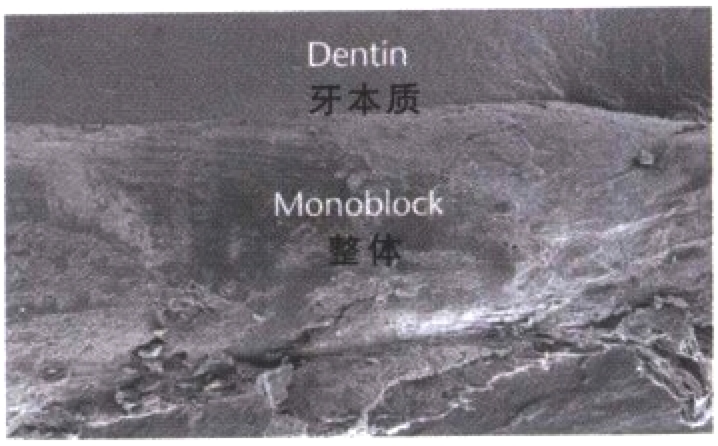




图 4–39　自酸蚀首涂剂可以清除根管壁上的沾污层并湿润管壁，降低表面张力。双向固化的树脂糊剂将树脂尖和根管壁结合在一起，形成一个整体

根管壁上的沾污层，并湿润管壁。自酸蚀首涂剂的表面张力较低，具有亲水性。然后将双向固化的树脂糊剂（图 4–39）充入根管；这种糊剂将根管壁和树脂尖粘结在一起形成一个整体，首次做到真正的根管封闭（图 4–40）。

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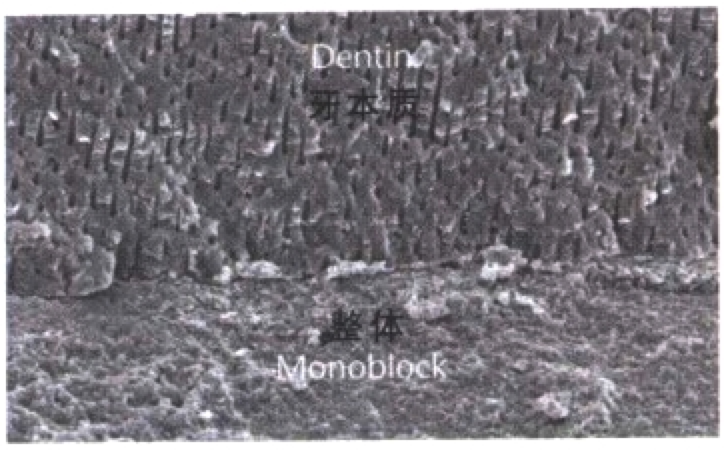


图 4–40 扫描电镜图，显示双向固化的树脂糊剂将树脂尖和根管壁结合在一起，形成一抵御细菌渗透的严密屏障

根管充填的临床操作步骤

1．根管预备一经完成，用 EDTA 进行最后一次冲洗，清除掉沾污层，并中和次氯酸钠对树脂粘结的影响。氯己定不影响树脂

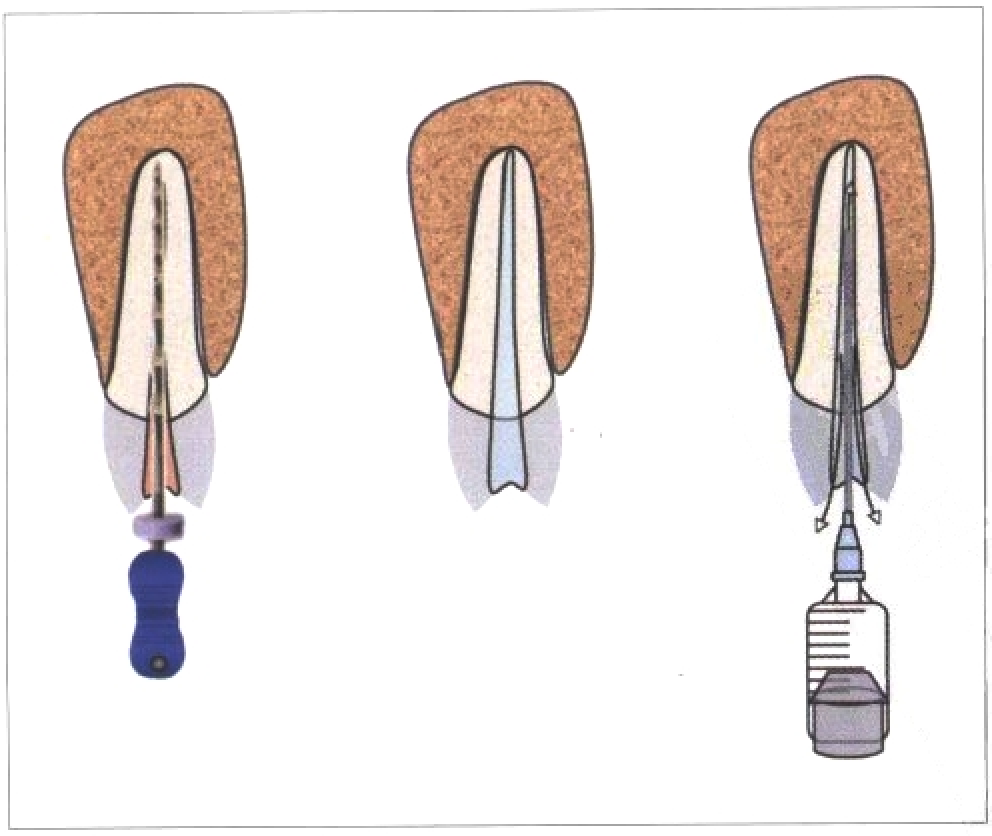


图 4–41 用次氯酸钠进行冲洗的根管预备结束后，最后用 EDTA 和（或）2% 氯己定冲洗根管

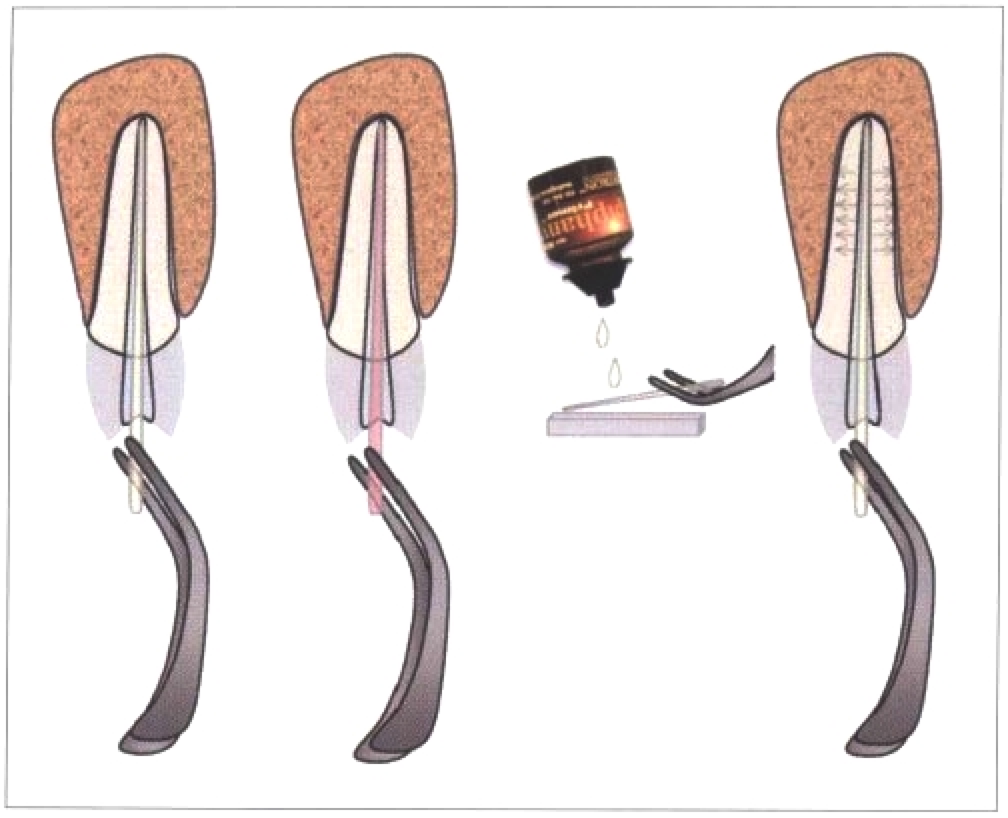


图4-42　用纸尖干燥根管，试树脂尖，然后将蘸满首涂剂的纸尖插至工作长度

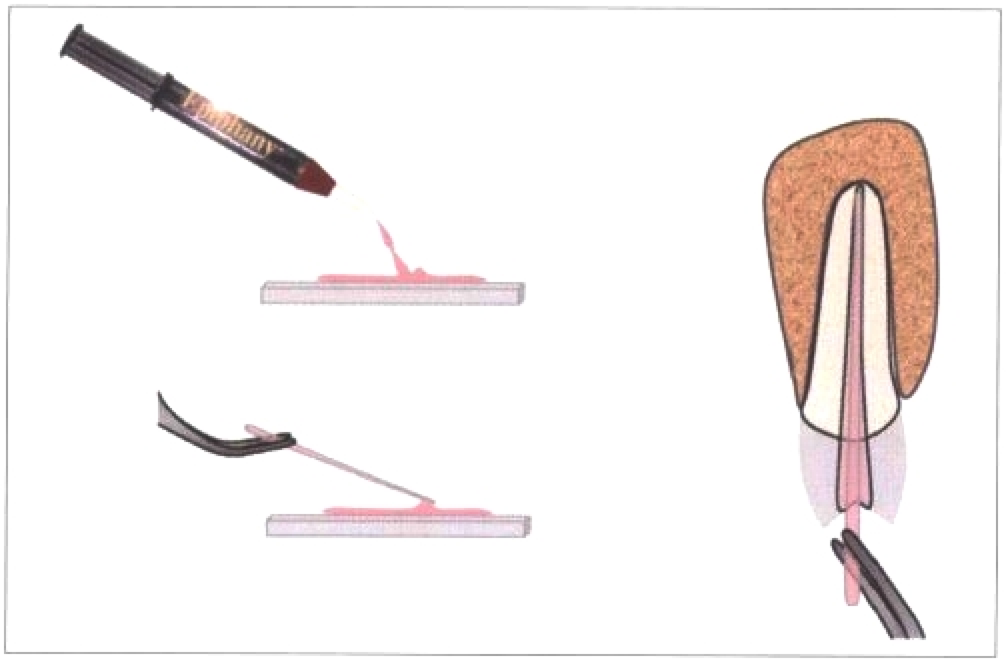


图4-43　将双向固化的树脂糊剂挤到调和板上，使树脂尖上涂满糊剂，插入根管后糊剂涂布在管壁上

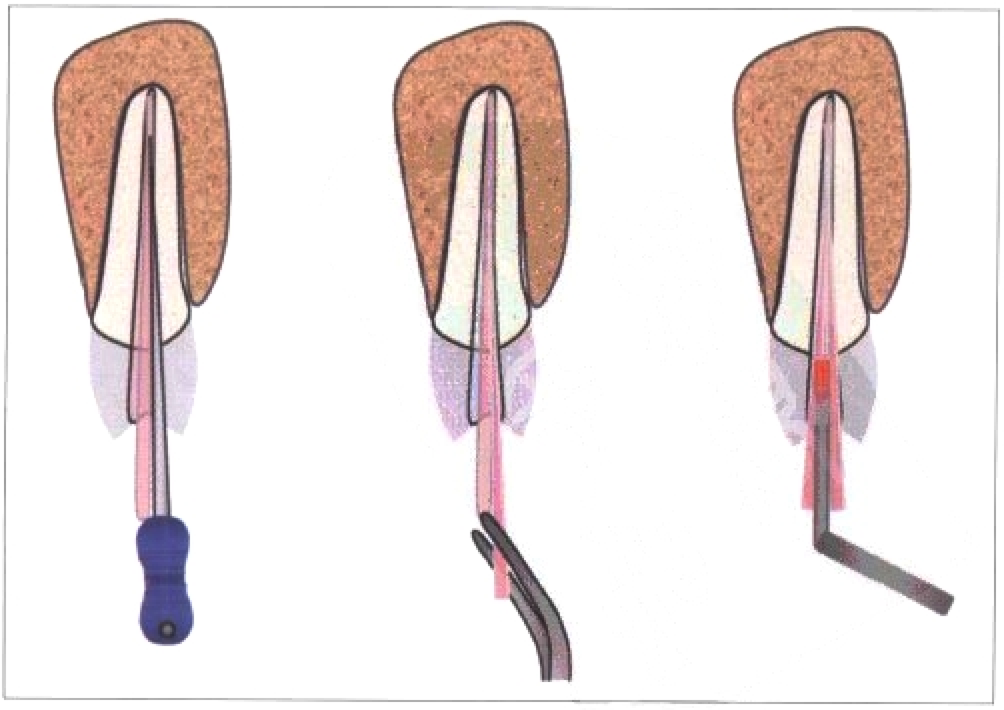


图4-44　侧压Resilon树脂尖。用轻力将侧压针插入到树脂主尖和管壁之间，挤压出空隙后再插入蘸满糊剂的辅尖。重复这一过程，直至根管中不能再插入树脂尖。用热器械切断多余的材料，然后用冷充填器对充填物进行垂直加压

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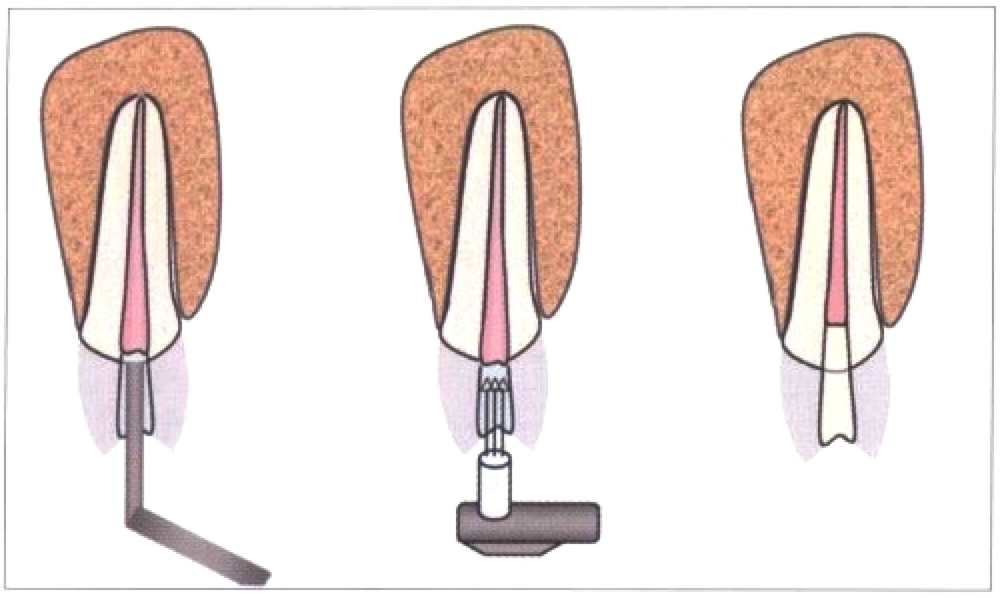


图 4-45　将多余的充填料清除至根管口水平，光照 40s 迅速形成冠方封闭，然后尽快进行最终冠修复

的粘结强度，可在使用首涂剂之前冲洗根管（图 4-41）。

2. 用纸尖干燥根管，将尺寸合适的 Resilon 主尖插入根管后 X 线照相，确定其长度适宜。将首涂剂滴在调和板上，用纸尖蘸满首涂剂后插至工作长度附近，再用干纸尖蘸吸出多余的首涂剂（图 4-42）。

3. 将树脂糊剂滴在调和板上调成适宜的稠度，再将糊剂涂满 Resilon 主尖，插入根管使糊剂涂布在根管壁上（图 4-43）。

4. 轻压侧压针在树脂尖和管壁之间形成空隙，再将辅尖蘸满糊剂后插入这一空隙，直到将管腔彻底填满为止。用热充填器切断树脂尖，接着用冷充填器轻轻垂直加压（图 4-44）。侧压树脂尖产生的力量一般小于牙胶尖。虽然这里只介绍了侧压法，其他热塑充填技术都可用于 Resilon 树脂系统，一般情况下，使 Resilon 树脂充分软化的温度要比牙胶尖低30℃，但使用前应将每个机器进行精确的调试。

5. 根充完成后，在髓腔的上方用光固化灯对充填物的表面照射 40s 左右，使根管的冠部马上得到密封。虽然树脂“整体”形

成了冠方封闭，还是应该尽早进行最终修复（图4–45）。

推荐读物

1.Hasselren G, Kerekes K, Nellestram P. pH changes in calcium hydroxide–covered dentin, J Endod 1987; 8:502–505.

2.Kerekes K, Tronstad L. Long–term results of endodontic treatment performed with a standardized technique. J Endod 1979; 5:83–90

3.Leonardo MR, Silva LAB, Almeida WA, Utrilla LS. Tissue response to an epoxy resin–based root canal sealer. Endod Dent Traumatol 1999; 15:28–32.

4.Shipper G,Ørstavik D, Teixeira FB, Trope M. An evaluation of microbial leakage in roots filled with a thermoplastic synthetic polymer–based root canal filling material(Resilon), J Endod 2004; 30:342–347.

5.Sundqvist G, Figdor D. Endodontic treatment of apical periodontitis. In: Ørstavik D, Pitt Ford TR(eds). Essential Endodontology: Prevention and Treatment of Apical Periodontitis Oxford:Blackwell–Munksgaard, 1998:242–277.

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7.Vertucci F. Root canal anatomy of human permanent teeth. Oral Surg Oral Med Oral Pathol 1984;58:589–597.

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5 牙髓病治疗的结果和预后

毋庸置疑的是，对于某一特定的患牙，只有在医生有足够的信心取得治疗成功的情况下才可尝试进行根管治疗。为取得最佳疗效，全科医生只应治疗条件理想的牙齿，而较复杂的牙齿则应转给牙髓病专家处理，这一点非常重要。另外，医生应熟知公认的不同牙髓疾病的治疗成功率，以便作出一个有把握的治疗计划。

对于不同的牙髓病病例，到底由全科医生治疗还是转诊给牙髓病专家，没有一成不变的规则，因为每个医生具有不同程度的处理问题的能力。作者认为，新技术的使用使医生能够治疗越来越多的病例。理论上，只要根管能够被小号的不锈钢锉探寻到，就可以使用旋转器械对其进行扩大和清理。

AAE牙髓状况难度评估表及使用说明

患者信息

姓 名：________________

地 址：________________

城市／州／邮编：________________

电 话：________________

意向

在诊室治疗： 是□ 否□

转诊患者至

____

日期：________________

使用 AAE 牙髓状况难度评估指导表的说明

AAE 所设计的牙髓病难度评估表用于牙髓病教程。该评估表使病例选择更有效、更一致和更容易记录。该难度评估表还可用来帮助牙科医生决定是否转诊和保存病史记录。

表中所列的状况应被视作可能使治疗复杂化或带来不利转归的风险因素。难度水平代表某些可能不受医生控制的状况的组合。风险因素能够影响医生取得稳定可靠治疗结果能力，并影响治疗过程和治疗质量。

执业医师可按照此评估表对具体病例的难度水平进行分级。

难度水平

低难度：术前条件提示复杂程度一般（不复杂），这类病例中各种因素仅属于低难度类。临床经验不太丰富的合格执业医生即可取得预期的治疗结果。

中等难度：术前条件复杂，一项或多项患者或治疗因素属于中等难度类。要想达到预期的治疗结果，对有经验的合格执业医生来说有一定难度。

高难度：术前条件异常复杂，多项因素属于中等难度类，或至少一个因素属于高难度类。要想达到预期的治疗结果，即使对于最富有经验的、长期保持良好治疗业绩的执业医生也是一种挑战。

总结你对每个病例的评估，确定其难度水平，假如难度水平超出了你的处理能力和经验，就应考虑将患者转诊给牙髓病专家治疗。

AAE 设计牙髓病难度评估表目的是帮助执业医师正确地处置患者，美国牙髓病协会既不表明也不暗示使用此表会保证带来有利的结果，此表可以被复制但不允许任何方式的修正与篡改。

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AAE牙髓病难度评估表

评估标准	低难度	中难度	高难度
A 患者状况			
病 史	□无疾病(ASA1)类	□患一种或几种疾病(ASA2)类	□病史复杂／严重疾病／残疾(ASA3～5)类
麻 醉	□无麻醉问题史	□不耐血管收缩药	□难以麻醉
患者性情	□合作顺从	□焦虑不安但合作	□不合作
张口度	□不受限	□轻度受限	□明显受限
呕反射	□无	□照相或治疗时偶尔作呕	□呕反射明显，曾影响治疗
急诊状况	□轻度疼痛或肿胀	□中度疼痛或肿胀	□严重疼痛或肿胀
B 诊断和治疗情况			
诊断	□症状和体征与发现的牙髓、根尖周状况一致	□需要对常见症状和体征加以深入的鉴别诊断	□症状与体征混乱复杂：难以诊断 □慢性口颌面痛史
放射诊断困难	□获得／解读放射照片低难度	□获得／解读放射照片（如高口底、狭窄或低腭穹隆、存在隆突）中难度	□获得／解读放射照片（如重叠的解剖结构）高难度
在牙弓的位置	□前牙／前磨牙 □轻度倾斜(<10°) □轻度扭转(<10°)	□第一磨牙 □中度倾斜(10°～30°) □中度扭转(10°～30°)	□第二或第三磨牙 □极度倾斜(>30°) □极度扭转(>30°)
牙齿隔湿	□可常规设置橡皮障	□需要进行简单术前改动以放置橡皮障	□需要进行较大术前改动以放置橡皮障
牙冠形态异常	□正常的原有冠部形态	□全冠修复 □烤瓷修复 □桥基牙 □冠、根中等变异牙（巨牙症、过小牙） □冠部大面积缺失	□修复体不能反映原有的解剖／排列 □明显的牙齿形态异常（融合牙、牙中牙）
根管和牙根形态	□轻度或无弯曲(< 10°) □根尖孔闭合(直径< 1mm)	□中度弯曲(10°～30°) □冠长轴与根长轴轻度不一致，根尖孔开放，直径1～1.5mm	□极度弯曲(>30°)或S形弯曲 □2根的下颌前磨牙或前牙 □3根的上颌前磨牙 □根管中或根尖1/3处分叉 □特长牙(>25mm) □根尖孔开放直径>1.5mm
根管的放射影像	□可见根管、管腔尺寸无减小	□根管和髓腔可见但腔隙减小 □髓石	□无法确定根管路径 □无根管影像
吸收	□无明显吸收	□轻度根尖吸收	□广泛的根尖吸收 □内吸收 □外吸收

AAE牙髓病难度评估表			
评估标准	低难度	中难度	高难度
C 其他状况			
创伤史	□发育完全或未完全牙齿的非复杂冠部折裂	□发育完全牙齿的复杂冠部折裂 □半脱位	□未发育完全牙齿的复杂冠部折裂 □根横折 □牙槽骨骨折 □撕脱 □内陷、伸出、侧方脱位
牙髓病治疗史	□无既往治疗史	□曾治疗但无并发症	□曾治疗伴并发症（如侧穿、根管不通畅、阶台、器械折断） □曾完成手术或非手术的牙髓治疗
牙周-牙髓状况	□无或轻度牙周病	□伴有中度牙周病	□伴有严重的牙周病 □并发牙周病的劈裂牙 □牙髓／牙周联合病损 □牙髓治疗前截根

美国麻醉学会（ASA）分类系统：

1类：无系统性疾病，患者健康

2类：患有轻微的系统性疾病，但无功能限制

3类：患有严重的系统性疾病，活动受限但能走动

4类：患有严重系统性疾病，患者不能走动，有时会危及生命

5类：无论是否进行外科干预，患者生命不超过24小时

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美国牙髓病医师协会（AAE）设计制作了下列牙髓病治疗难度评估指导表（经AAE许可印刷），以帮助全科医生确定哪些牙髓病可以自己治疗、哪些需要转诊给牙髓病专家治疗。

同大学进行的有关牙髓病治疗结果的研究显示整体成功率大约为90%。但是，横断面调查和回顾性研究的结果却显示根管治疗的成功率仅为60%～75%。横断面调查发现根管充填不良与出现根尖周阴影之间持续相关，但许多流行病学研究则揭示一些治疗前、治疗中和治疗后的因素可以影响牙髓病治疗的预后。

影响牙髓病治疗预后的因素

治疗前因素

文献中提及的可能影响根管治疗预后的术前因素包括：年龄、性别、全身健康状况、牙齿位置、牙髓状况、症状、病损的范围和牙周状况等，但是，只证实根尖周炎会影响治疗的预后，存在根尖周炎的患牙比术前无根尖周炎患牙的治疗成功率低10%～25%。治疗根尖周炎的低成功率反映了对确立的疾病进行预防（对无菌的挑战）和治疗（对消毒的挑战）之间的差异。这种较差的疗效也反映出对根充之前进行根管消毒的重要性缺乏足够的认识。我们确信，如果完全遵循本手册所叙述的治疗方针，无论患牙治疗前有无根尖周炎，同样都会达到较高的成功率。

在很多进行再治疗的病例中，是否存在术前根尖周炎对治疗结局有决定性影响。这也反映出对原先治疗过的牙齿进行根管消毒更加困难。

与治疗相关的因素

诸多与治疗相关的因素可以影响牙髓病的治疗预后，包括根管充填材料在根尖部的位置、根尖部的扩大程度、诊疗的次数、所用材料和技术以及治疗的并发症等。对于存在根尖周炎症的患牙，根管充填材料超出根尖孔通常会导致成功率降低，但对根尖周健康的牙齿影响不大。研究发现，在感染根管中根充材料距X线根尖1mm以上时，其预后要比根充材料距X线根尖0.5～1mm时差。在非感染根管中，根充材料距X线根尖在0～2mm范围内都可达到相近的高治愈率。另外，用氢氧化钙进行根管内封药可提高根尖周炎患牙的治愈率。一些研究证实，应用改良逐步后退技术预备根管可将成功率提高近9%。此外，所用根管糊剂的不同可能影响治疗的预后。治疗的并发症如根分叉区穿孔、根管锉折断、根管糊剂超充等因素仅仅占到牙髓治疗失败原因的4%。

牙髓治疗的转归和预后

* 无根尖周病损的活髓和死髓牙：90%～98%
* 伴有根尖周病损的死髓牙：80%～90%，根管条件较差时可降至50%～60%
* 无根尖周病损的根管再治疗牙：89%～96%
* 伴根尖周病损的根管再治疗牙：60%～74%

图5－1

治疗后的影响因素

现在越来越清楚的是，根管治疗后的冠方微渗漏可能导致根管的感染，继而使治疗失败。冠方修复能够起到保护根管充填物

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的作用，并为防止根管再感染提供额外的屏障。对于使用牙胶尖和糊剂充填根管的牙齿，其冠方修复比根管充填在预防冠方微渗漏方面更有效，也更重要。

在过去的80年中，发表了大量有关根管治疗结果和预后的文章，其中大部分的研究在所用材料的成分、治疗程序、治疗方法等方面差异相当大，因而无法进行比较并得出可靠的结论。然而，从这些研究中累积的信息使我们可以预见牙髓病治疗的转归（图5–1），并可得出以下的大体结论：

* 如果牙髓治疗操作完美，成功率就会相当高。

* 牙髓治疗失败的原因几乎全部源于根管腔感染和其对根尖周组织的影响。

* 根管感染常与根管预备和充填不充分以及冠部修复不当有关。

术后随访

由于牙髓治疗会发生失败，因此，治疗结束后6～12个月应该进行临床及X线检查随访，如果需要，特别是对于那些存在根尖周炎的牙齿，观察期限可延长至4年。

推荐读物

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附录 英文原文

Endodontics Manual for the General Dentist

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Preface

Root canal therapy requires a high level of technical skill. However, without a correct diagnosis and a clear understanding of the biologic fundamentals governing a successful outcome, a clinician's skills may be wasted on complicated techniques or inappropriate treatments. A correct diagnosis, in combination with the right choice of new materials and techniques, will ensure an environment that offers an extremely high probability of success and a healthy apical periodontium. The authors hope that, after reading this manual, you will find the practice of endodontics simple—and predictably successful.

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1

Introduction to Endodontics

Before proceeding to the specifics of endodontic treatment, it is extremely important for the dentist to have a clear understanding of the *clinical* definition of endodontics. As part of the health care profession, each dental specialty needs to be focused on a specific disease. For endodontics, the disease of interest is *apical periodontitis*—periodontal attachment inflammation at the apex of the tooth. In rare cases, periodontitis of endodontic origin may be located in a position other than the apex of the tooth; these cases are described as *peri-radicular periodontitis*. Apical periodontitis manifests as pain originating from the apical periodontium or, more commonly, as (pain-free) radiolucency on the radiograph (Fig 1-1). Histologically, it resembles a granuloma or cyst (Fig 1-2).

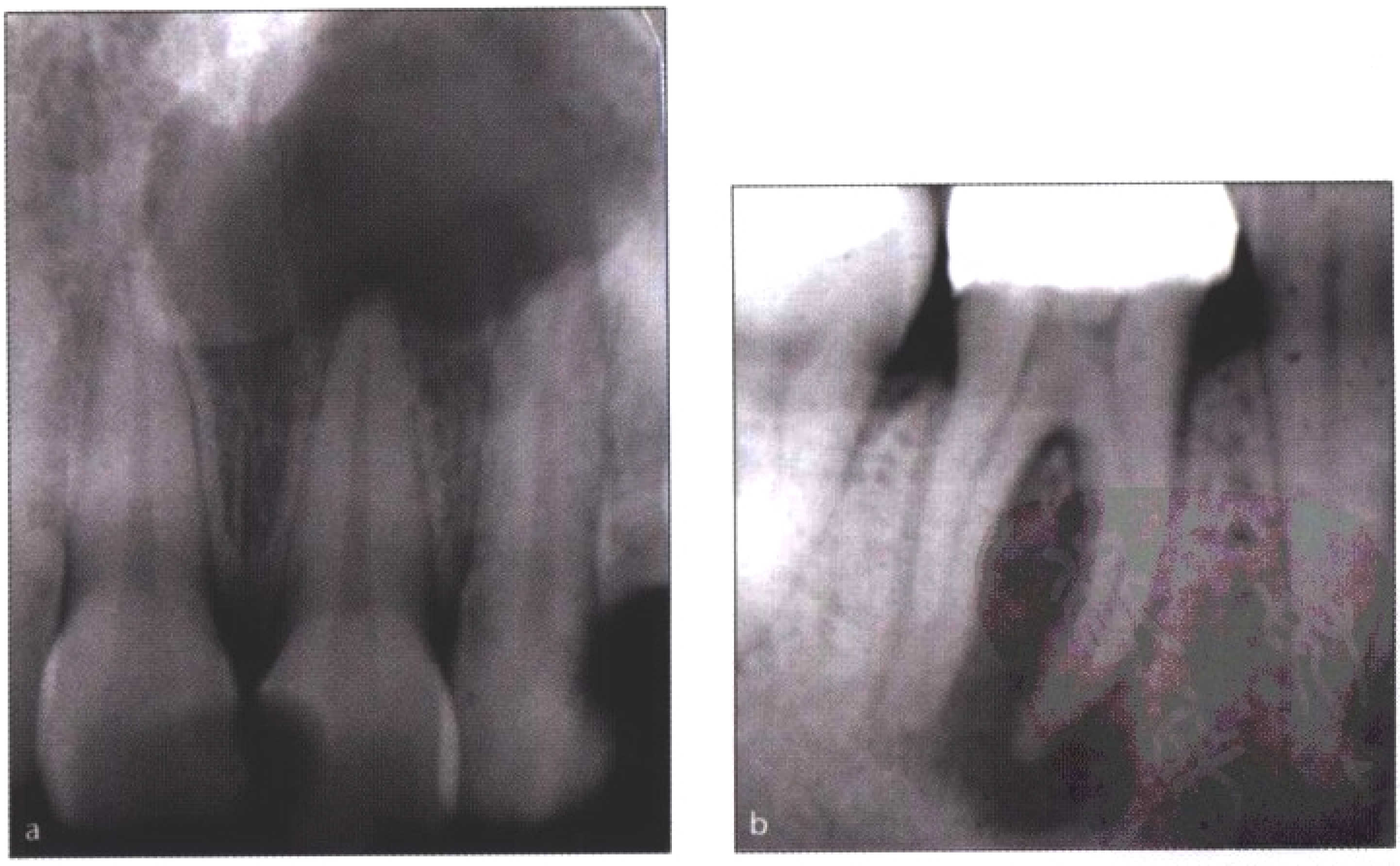


Fig 1-1 *(a)* Maxillary central incisor with chronic periodontitis manifesting as a radiolucency. *(b)* Mandibular molar with radiolucency typical of periradicular periodontitis.

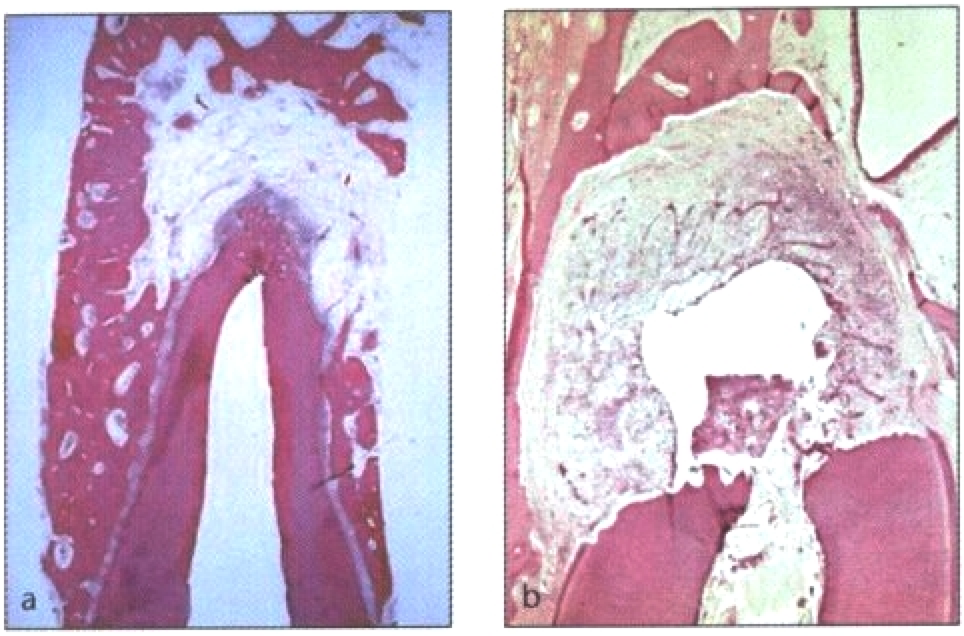


Fig 1-2 Histologically, a periapical lesion will sometimes appear as *(a)* a granuloma, or *(b)* a cyst.

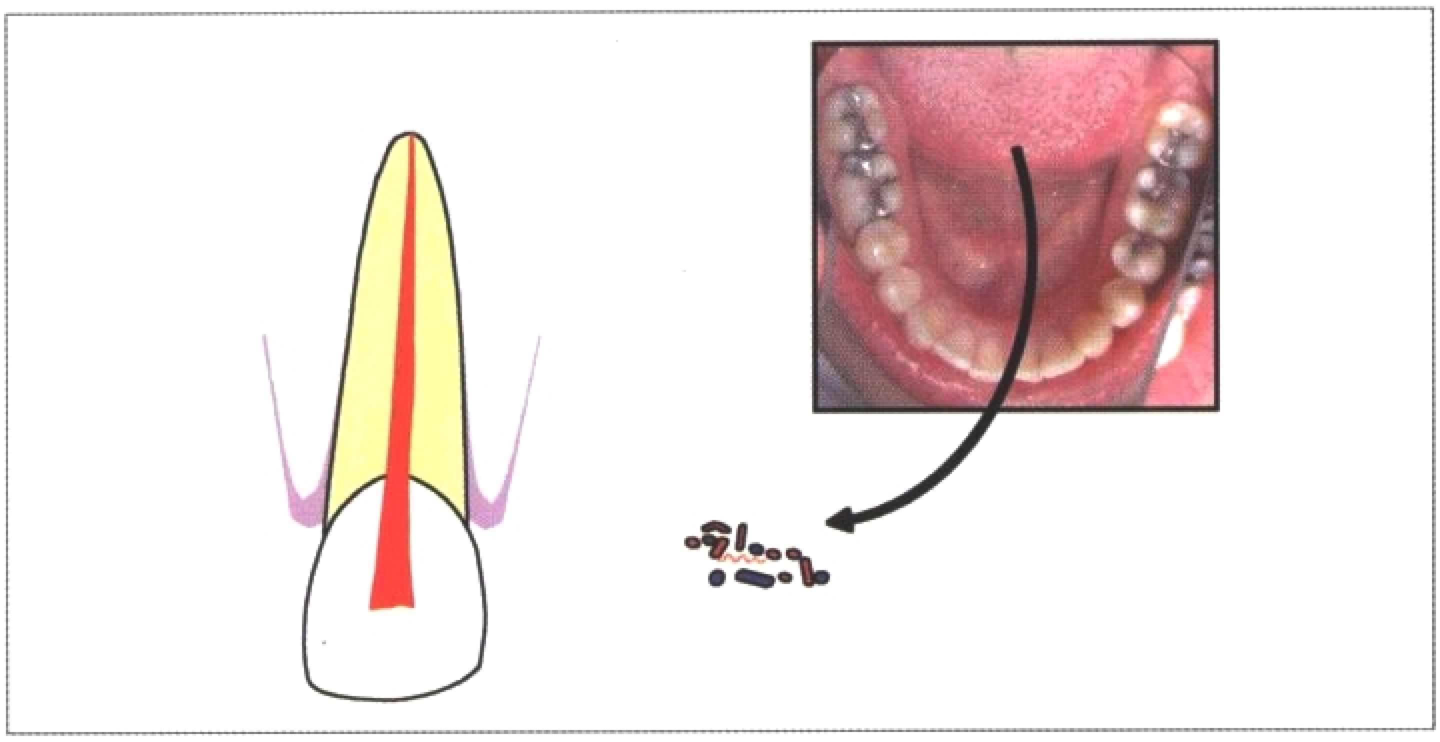


Fig 1-3a Oral microorganisms represent a constant threat to the health of the pulp. In addition to the immune response of the vital pulp, the enamel and dentin serve as physical barriers against their invasion, thus preventing apical periodontitis.

In apical periodontitis, a majority of the pulp space must be infected (Figs 1-3a to 1-3c). And for such a well-established infection to be present in the root canal system, the pulp must be necrotic. **Therefore, from a clinical perspective, a tooth with apical periodontitis of endodontic origin will test nonvital to sensitivity tests!**

If apical periodontitis is characterized by an infected and necrotic pulp, an obvious question is, What role does the vital pulp have in endodontic disease? If it is true that

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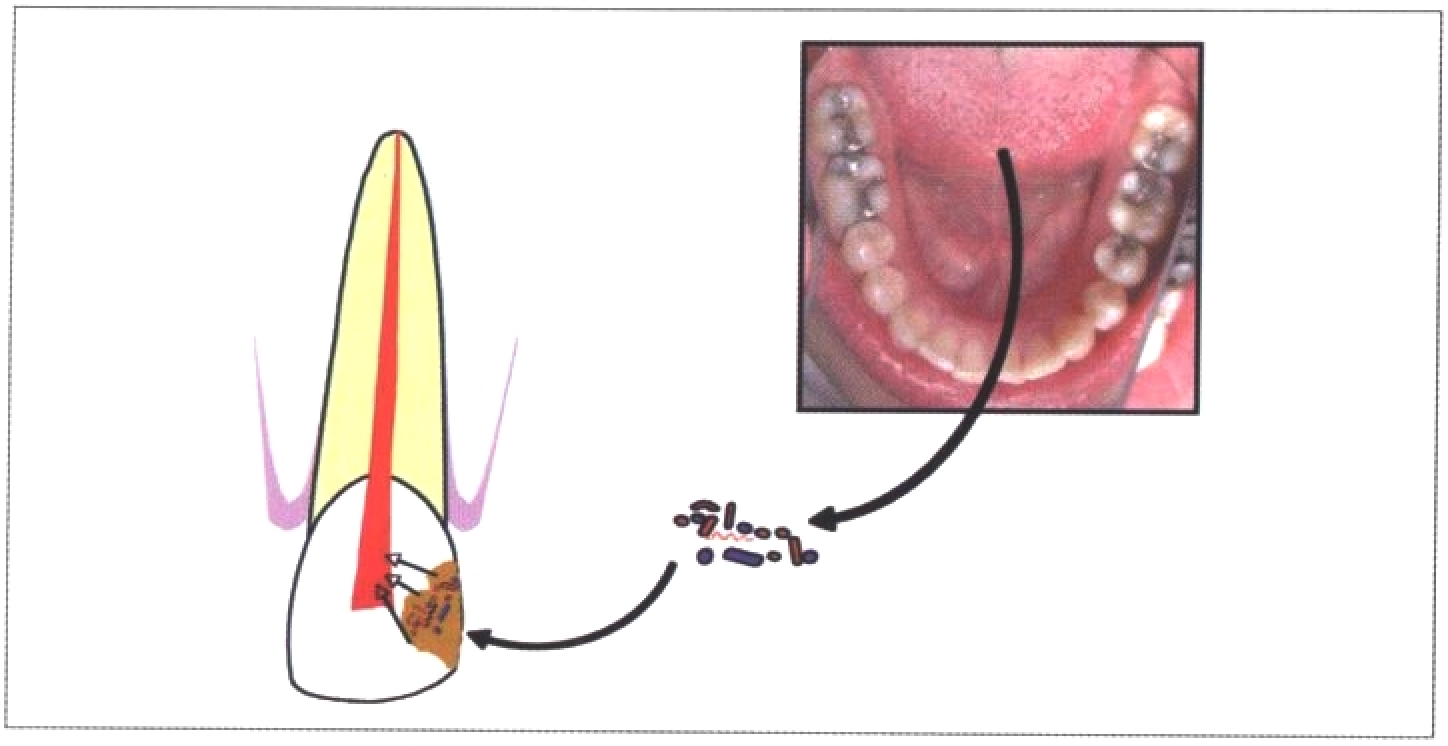


Fig 1-3b If the microorganisms are able to penetrate the enamel and dentin, the pulp will exhibit an inflammatory response (reversible or irreversible). If the pulp is directly exposed to the microorganisms, a zone of necrosis circumscribed by a zone of inflammation will develop. Over time, the necrotic zone will enlarge, pushing the circumscribed zone of inflammation toward the apex.

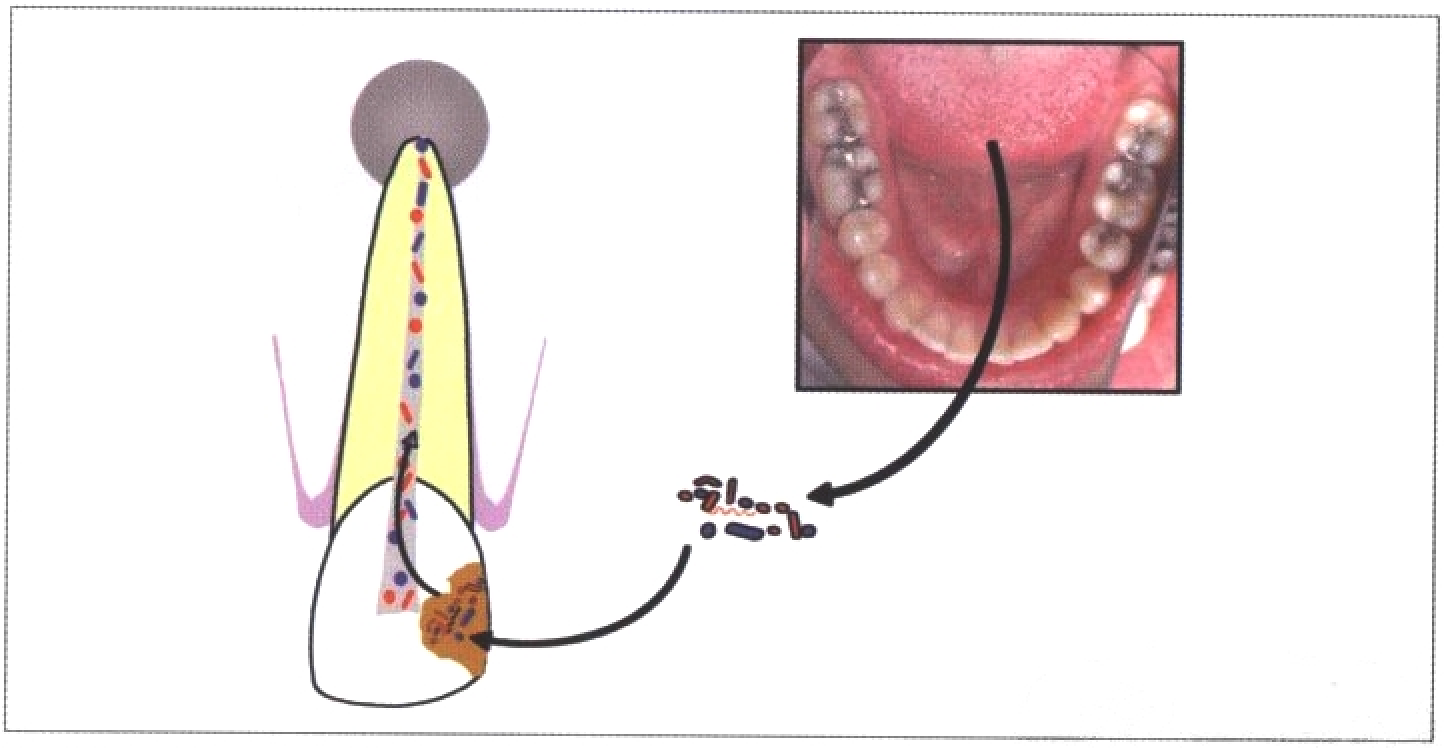


Fig 1-3c When most of the pulp is necrotic, the inflammation will move through the apical foramen, resulting in apical periodontitis.

necrosis and infection are essential components of the disease, it is also true that a pulp that is found to be "mostly" vital cannot be diagnosed as apical periodontitis of endodontic origin. **Therefore, maintenance of pulpal vitality or removal of the pulp while it is still vital will prevent the development of apical periodontitis.**

Thus, endodontics is the prevention or elimination of apical periodontitis. Prevention of apical periodontitis is achieved by vital pulp therapy, and elimination of apical periodontitis is achieved by a disinfection protocol of the root canal system.

As will be explained in a later chapter, a vital pulp cannot be considered as requiring the same treatment strategy as a necrotic infected pulp if one is to expect the same probability of success in both cases.

Vital Pulp Therapy

Vital pulp therapy can be divided into two categories: treatment of *reversible pulpitis* and treatment of *irreversible pulpitis*. These diagnostic terms imply that if a group of teeth with the history, signs, and symptoms of a reversible pulpitis were treated with standard operative procedures, most of the pulps would be expected to reverse to a healthy state. Since a healthy pulp cannot be associated with apical periodontitis of endodontic origin, treatment that will reverse an inflamed pulp to health is the best endodontic treatment that can be performed (Fig 1-4).

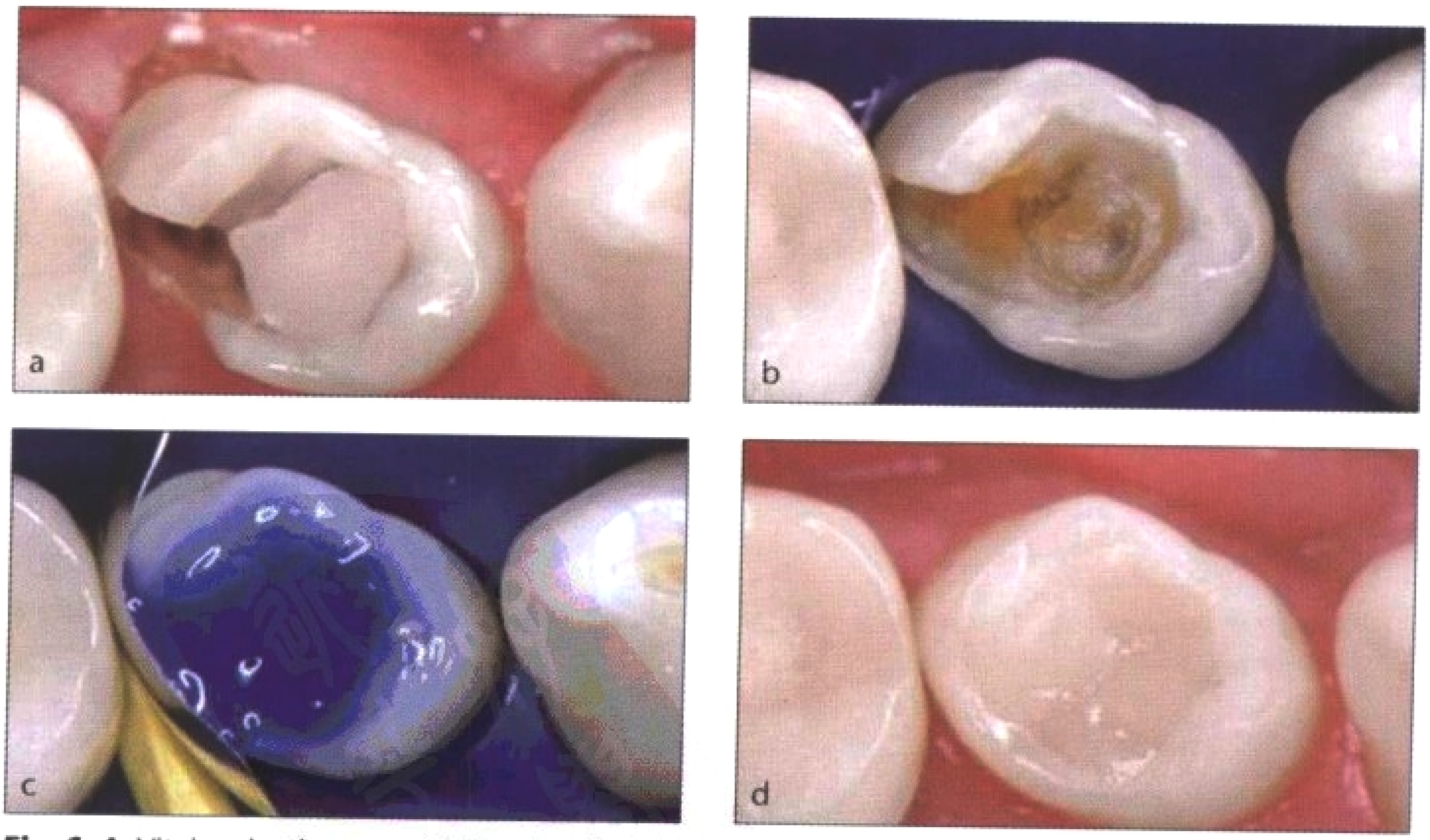


Fig 1-4 Vital pulp therapy. *(a)* Tooth with a failed restoration and recurrent caries diagnosed as reversibly inflamed; *(b)* Removal of caries; *(c)* Acid placement in preparation for a resin-bonded restoration; and *(d)* Final restoration. (Courtesy of Dr Andre Ritter.)

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Conversely, if a group of teeth with a diagnostic presentation consistent with irreversible pulpitis were treated as above, then many of the pulps would become necrotic, infected, and develop apical periodontitis. Thus, the best preventive treatment in such cases would be aseptic removal of the entire pulp (pulpectomy) and filling of the root canal and coronal access (Figs 1-5 and 1-6).

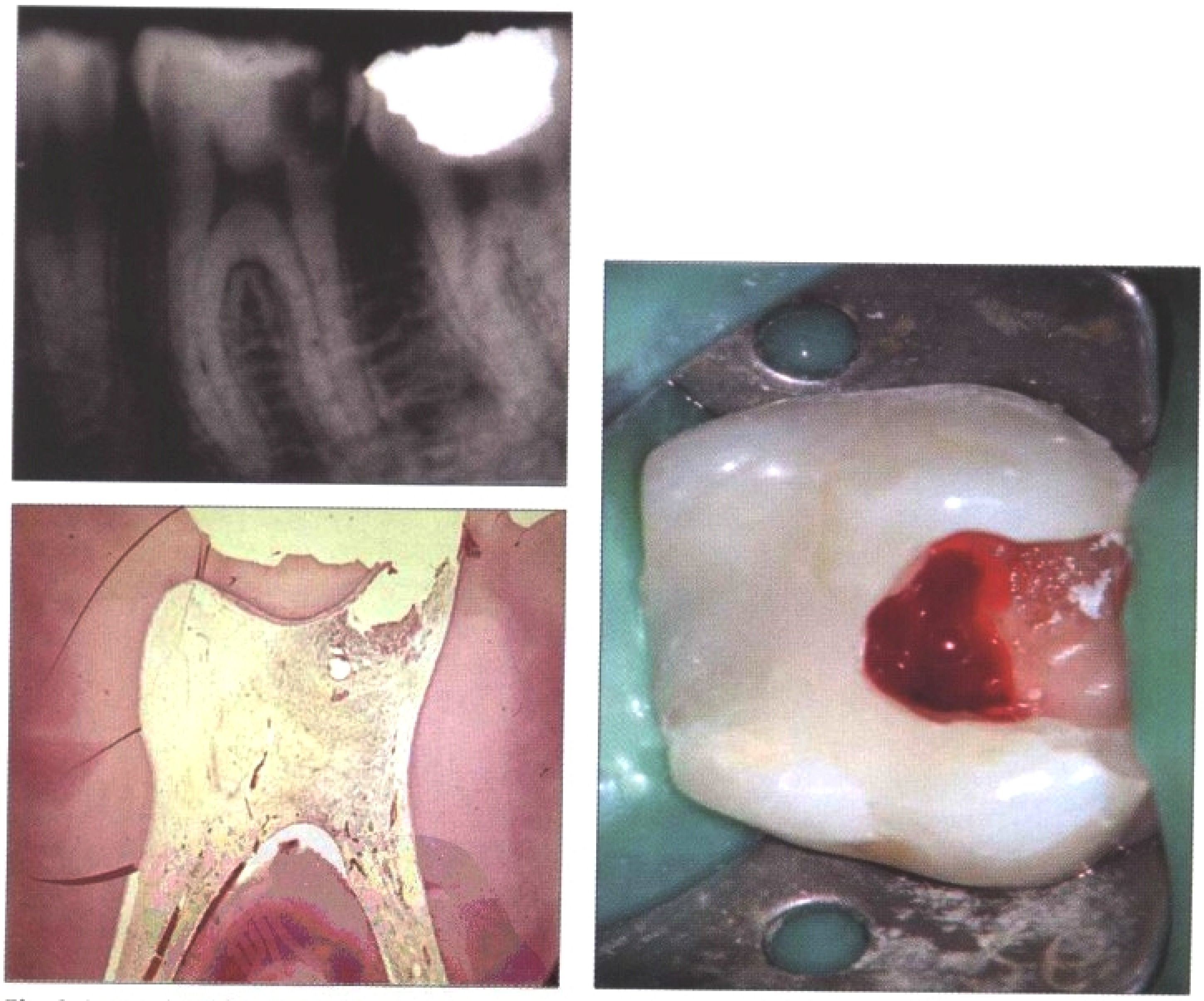


Fig 1-5 Tooth with exposed caries and symptoms of irreversible pulpitis (see Chapter 2). The most predictable treatment for the prevention of apical periodontitis is pulpectomy. (Courtesy of Dr Leif Tronstad.)

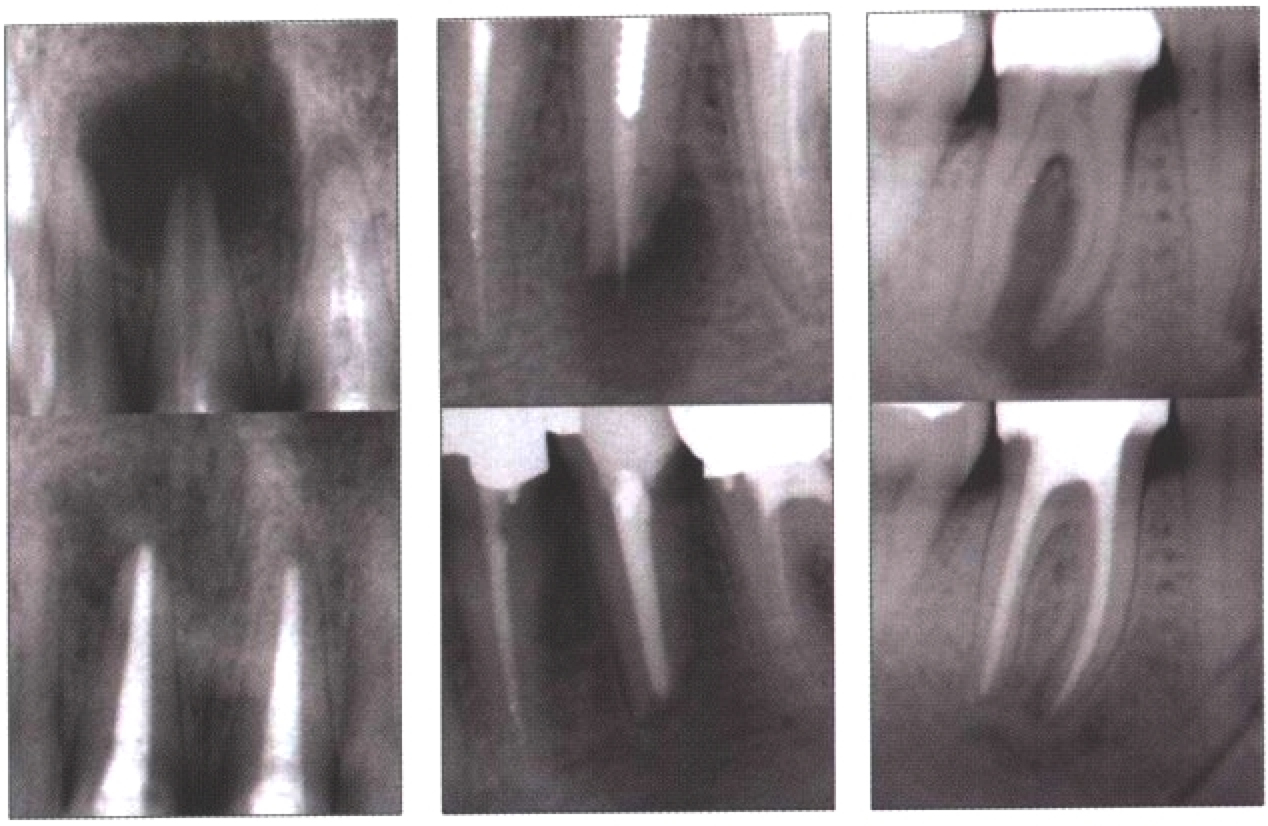


Fig 1-6 Pre- *(top)* and post-treatment *(bottom)* radiographs demonstrating healing in cases of distinct apical periodontitis.

Necrotic Pulp Therapy

Since microbes are the cause of apical periodontitis removal of the microbes should reverse the disease. A high probability of success in reversing apical periodontitis can be expected if the microbial count is lowered to negligible levels and the entire cavity (root canal and access cavity) is quickly and adequately filled and sealed.

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2 Diagnosis of Reversible Pulpitis, Irreversible Pulpitis, and Necrotic Pulp

As described in Chapter 1, different treatment approaches are needed for teeth diagnosed with reversible pulpitis, irreversible pulpitis, and necrotic pulp. Therefore, it is important to be able to recognize the diagnostic features that differentiate these three diagnostic categories.

While the type of pain experienced by the patient is often the factor that differentiates one diagnostic category from another, it should be emphasized that pain is the exception in both pulpitis and apical periodontitis (Fig 2-1). Therefore, clinical findings and knowledge of the reaction pattern of the pulp are essential in making a correct diagnosis.

It should also be acknowledged that the diagnostic tools presently used in dentistry are very primitive and rather inaccurate. For this reason, it is essential to gain as much information as possible from a number of different tests rather than to rely on one

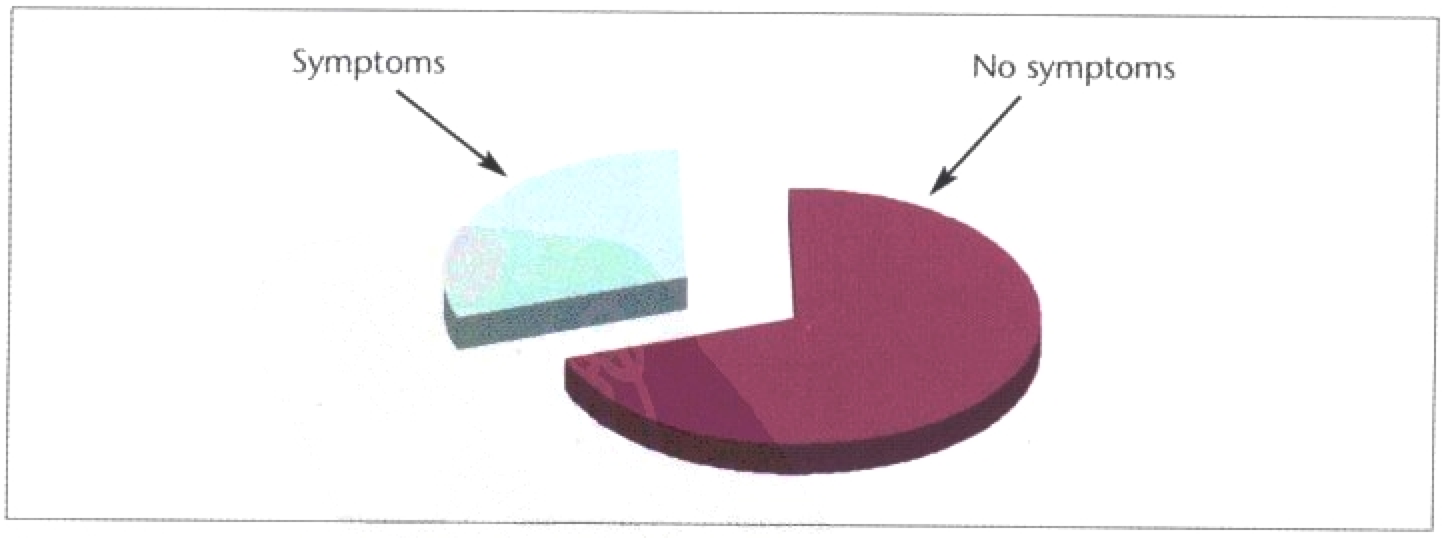


Fig 2-1 Proportions of patients with and without symptoms in cases of pulpitis and periodontitis.

particular favorite test. Ultimately, the practitioner must make as educated a guess as possible. But even the most careful and skilled practitioners can make incorrect diagnoses. For this reason, it is essential to follow up your patients and recheck the diagnosis. **Lack of pain is not the ultimate sign of success and in many cases is only temporary!**

The diagnosis is made after careful analysis of symptomatology, diagnostic tests, and the clinical exam.

Symptomatology

Chief complaint

The patient should be asked to state what brought him or her to your office. This could provide important clues about the status of the pulp and whether it is vital or necrotic, reversible or irreversible (Fig 2-2).

Symptoms Associated with

Reversible Pulpitis	vs	Irreversible Pulpitis
Pain-free		Pain-free
Sharp pain		Deep dull throbbing pain
		Pain to cold and hot liquids
		Pain to heat, relieved by cold
		Pain on biting

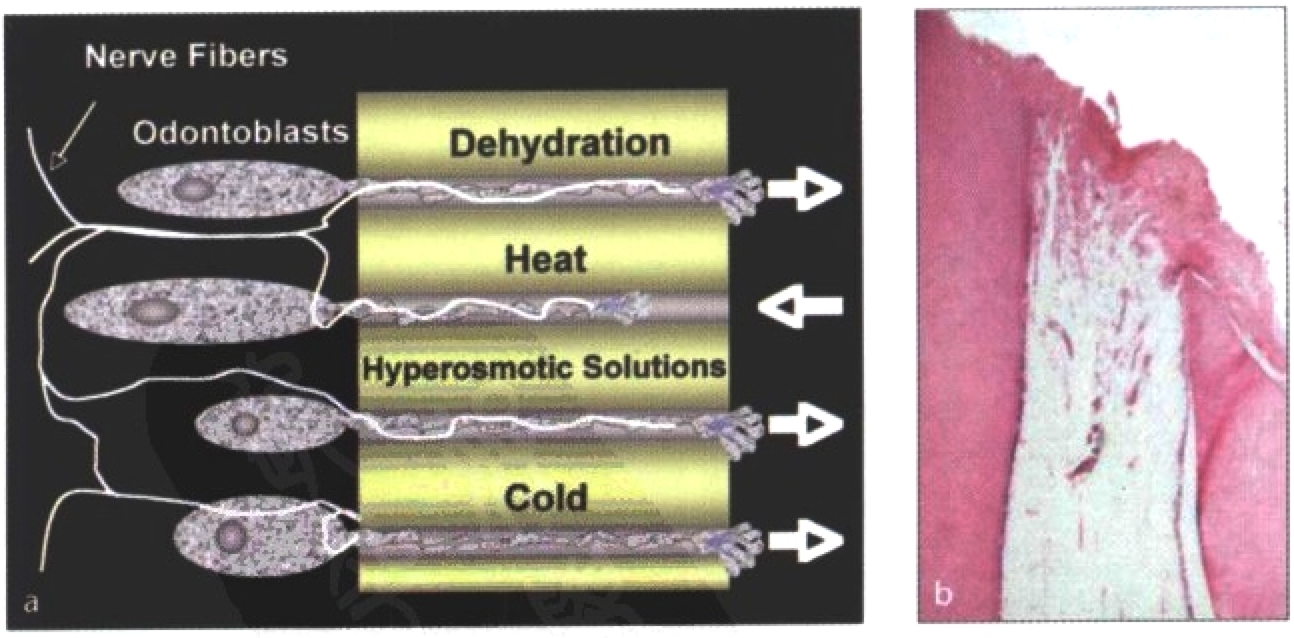


Fig 2-2 Reversible and irreversible pulpitis differ primarily in the nature of the pain each one causes. *(a)* Peripheral A-δ fibers cause sharp pain on stimulation. *(b)* Central C fibers cause severe, dull, throbbing pain.

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Vital pulp: (a) No complaint, or (b) pain on contact with cold or hot liquids or with salty or sugary substances.

Necrotic pulp: (a) No complaint, or (b) pain on biting, pressure, constant pain. No pain in response to temperature. Pain can be but is not necessarily severe. Note: When the presenting symptoms confirm both vital and necrotic pulp, a cracked cusp or tooth should be suspected.

Reversible pulpitis: No complaint, or pain (usually mild) on contact with cold or hot liquids or with salty or sugary substances. Pain is sharp and goes away when the cold, heat, salt, or sugar is removed. Pain is not considered severe.

Irreversible pulpitis: No complaint, or pain on contact with cold or (particularly) hot liquids or with salty or sugary substances. Pain is severe, exploding, deep, dull, gnawing, pulsating, gaseous.

Differentiating features

Reversible pulpitis: Mild to moderate pain. Pain is sharp.

Irreversible pulpitis: Severe pain. Pain is deep, dull, gnawing, exploding, gaseous.

History of the chief complaint: The clinician must fill in any gaps left out by patients in their description of why they sought treatment.

Necrotic pulp: Questions should be asked to confirm that the pain is not temperature related and is present on biting, pressure, etc.

Reversible vs irreversible pulpitis: To differentiate between reversible and irreversible pulpitis, the patient should be questioned until some critical differentiation are made.

Nature of the pain

A key differentiation between reversible and irreversible pulpitis is the nature of the pain (if present). Reversible pulpitis is more likely when the peripheral A-δ fibers are stimulated. Stimulation of these fibers results in sharp, knife-like pain. If the centrally located C fibers are stimulated, however, the pain will generally be described in terms of severe, deep, dull, gnawing, and lingering. The latter descriptions are indicative of irreversible pulpitis.

History of the pain

In reversible pulpitis, the patient will usually report having had no previous experience of pain from that particular tooth. If the patient reports a past history of pain from the

same tooth and describes it as spontaneous unprovoked pain, pain that wakes the patient at night, or heat-sensitive pain that is relieved by cold liquids, a diagnosis of irreversible pulpitis can confidently be made. In addition, severe pain that is difficult to locate accurately (referred pain) is indicative of irreversible pulpitis.

At this stage, the clinician should have a very good idea of how to diagnose the tooth in question. The remainder of the diagnostic process is directed toward determining which tooth fits this diagnosis.

Diagnostic Tests

As noted earlier, the tests used to diagnose pulpitis or necrosis are subjective and rather primitive. As such, when testing a suspicious tooth, the results should always be compared with the results elicited from a tooth that is thought to be healthy. The tests should also be repeated a few times to ensure that the patient's response is consistent. Generally, diagnostic tests are able to differentiate only between a necrotic and a vital pulp. They are presently not sensitive enough to differentiate between a reversible and an irreversible pulpitis.

Thermal tests

Thermal tests rely on fluid flow in the dentinal tubules. When cold or heat is placed on a tooth, the fluid movement in the dentinal tubules will result in irritation of the peripheral pulp tissue, including the A-δ fibers. A sharp "pain" will result. If the pulp is severely inflamed, it is also likely that the expansion (heat stimulation) or possibly that the contraction (cold stimulation) of the pulp tissue may cause stimulation of the centrally placed C fiber as well.

Cold test

The cold test should be performed using either dichlorodifluoromethane (–40°C) or carbon dioxide snow (–70°C). These agents are far superior to ethyl chloride (–4°C) or an ice stick from the freezer, which tends to melt on contact with the tooth and spread the cold to other teeth. For anterior teeth, the cold should be placed on the incisal third, for posterior teeth on the incisal aspect of the mesiobuccal cusp. These areas approximate the pulp horns, where the nerve innervation of the pulp is most plentiful (Fig 2-3). Before retesting the same tooth, the pulp should be allowed time to recover.

A consistently negative response is 97% proof that the pulp is at least partially necrotic and therefore in need of endodontic treatment. A positive response indicates a vital tooth. Unless the response is definitely of C fiber origin (deep, dull, gnawing, exploding), a positive response to cold in itself is not a sufficient basis to determine whether the pulp is reversibly or irreversibly inflamed.

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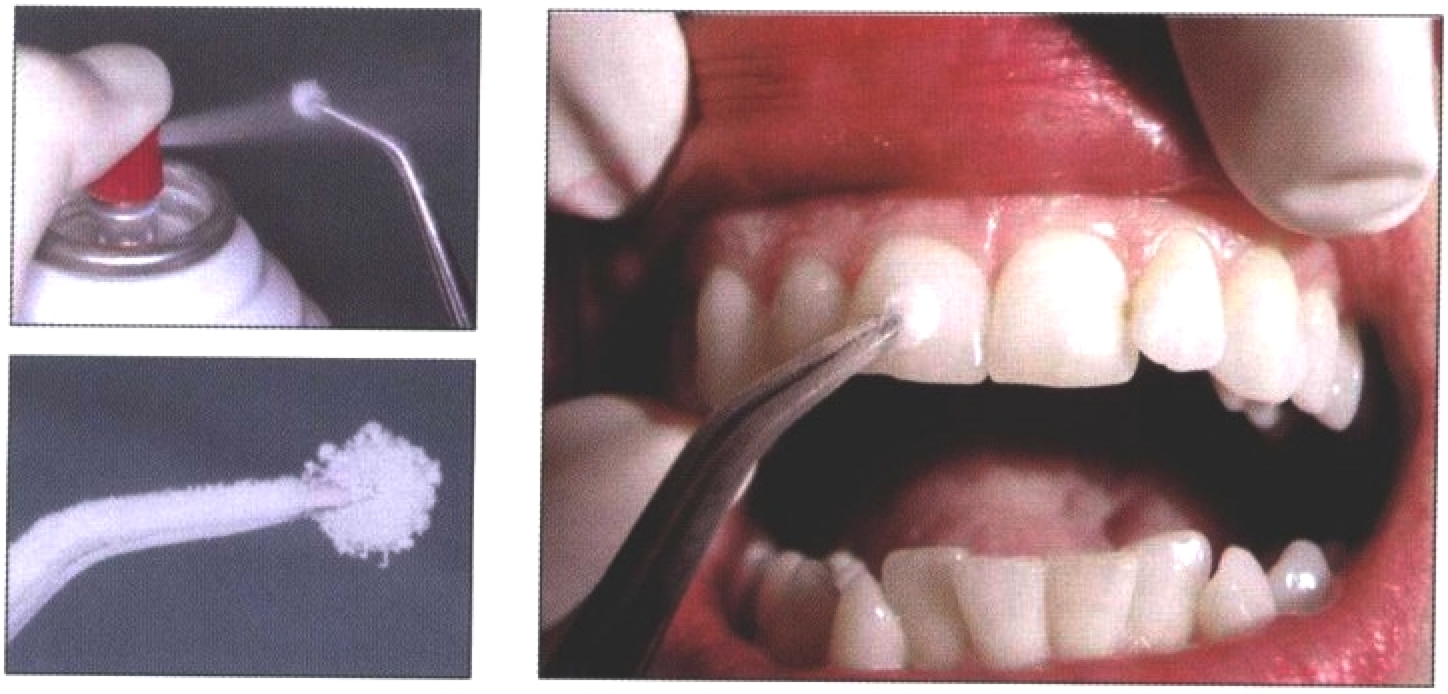


Fig 2-3 The most effective agents to use for the cold test are dichlorodifluoromethane (–40°C) *(shown here)* or carbon dioxide snow (–70°C), which should be placed in direct contact with the incisal third of the buccal surface of the tooth. The test can also be performed with an ice stick or ethyl chloride (–4°C).

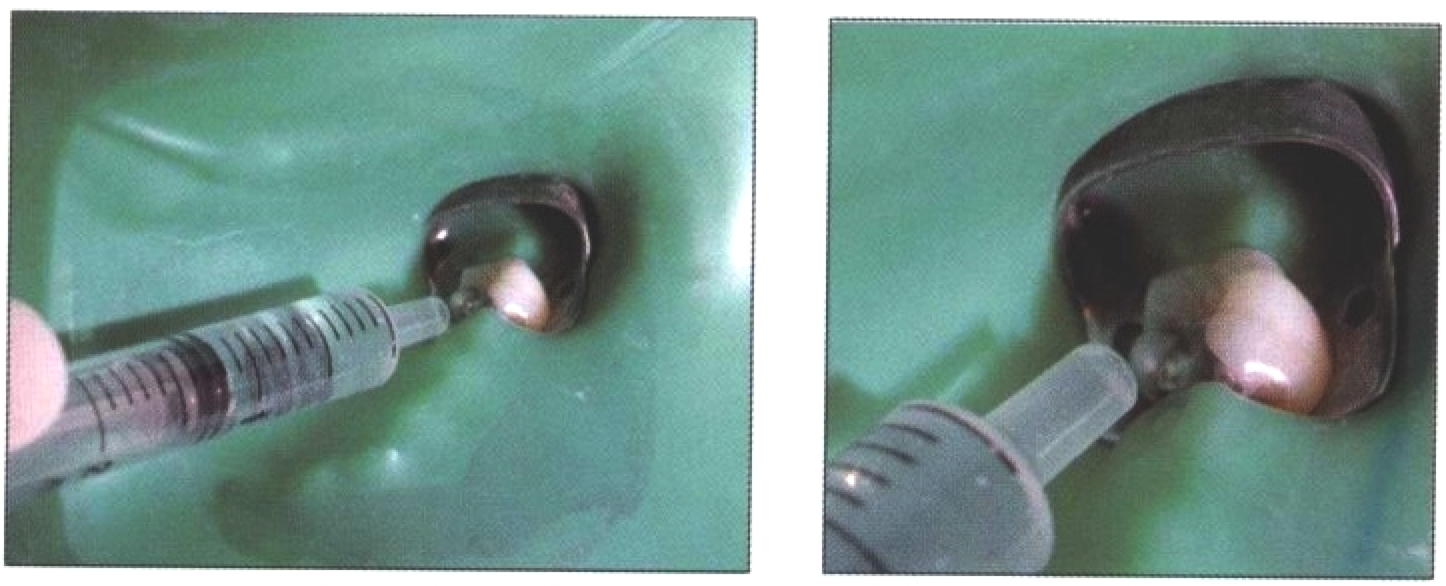


Fig 2-4 For the hot test, the tooth in question is isolated with a rubber dam, and hot water is gently squirted through a syringe until the entire tooth is covered. This protocol can be repeated several times using fresh hot water.

Hot test

At present, an effective hot test has not been devised. The best method of testing for heat sensitivity is to bathe the tooth in hot water. The first step is identifying the offending quadrant. Next, with the patient in a supine position, a rubber dam is placed on the most posterior tooth in the quadrant. A syringe is used to squirt hot water gently over the tooth until the entire tooth is covered (Fig 2-4). If this test does

not reproduce the patient's symptoms, the rubber dam is repositioned on the tooth anterior to the tested tooth and the test is repeated using fresh hot water. This protocol is repeated until the pain is replicated. As with the cold test, a consistently negative response indicates a tooth that requires endodontic treatment. However, a positive response in itself cannot differentiate between reversible and irreversible pulpitis.

Electric pulp test

The electric pulp test (EPT) measures pulpal vitality through direct stimulation of the nerve fibers of the pulp. It is particularly effective in older teeth and in teeth that have limited fluid flow through the tubules due to dentinal sclerosis and obliteration. Again, the incisal third for an anterior tooth and the incisal third of the mesiobuccal cusp for a posterior tooth are the most effective areas for the EPT (Fig 2-5). As with both the hot and cold tests, a negative response is indicative of necrosis while a positive response merely indicates vitality.

Test cavity

When a previous restoration prevents thermal or electrical stimuli from passing through it, none of the diagnostic tests described here will be effective. In such cases, the only option is to drill a window into the restoration to allow the tests to be performed. Since drilling into the crown and dentin produces fluid flow in the tubules, this in itself, when performed without anesthesia, is an effective measure of pulpal vitality and is commonly referred to as a *test cavity*. In our opinion, test cavities should be performed only as a last resort and always in a situation that anticipates a normal or reversibly inflamed pulp. When performing a test cavity, copious water spray and feather touch drilling should be used.



Fig 2-5 For the electric pulp test, an electrode is placed in contact with the incisal edge of the tooth to be tested. Toothpaste is used to ensure good contact.

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Percussion and palpation

Percussion and palpation are used to evaluate the presence of periodontal inflammation. Since periodontal inflammation will be present in a necrotic pulp in the vast majority of cases, a positive percussion or palpation test is a useful additional indicator of apical periodontitis when the tooth has been nonresponsive to thermal tests or to EPT.

Also, it is possible that as it becomes necrotic, an irreversibly inflamed pulp can quickly lead to inflammation of the periodontal tissues, particularly through furcal canals or accessory canals that are high up on the root. If periodontal inflammation exists in a vital tooth, it is assumed that the root pulp is inflamed and thus reversibility of the pulpitis is unlikely. Therefore, a positive (hypersensitive) percussion or palpation test in a vital tooth is indicative of irreversible pulpitis.

The percussion test should be performed so that as much of the root surface periodontal ligament is "irritated" as possible Using the back of a mirror or another metal instrument, tap the tooth along the long axis of the root, since in most cases the inflammation will be at the apex of the tooth (Fig 2-6). The tooth should also be tapped in as many directions as possible to cover as many root surfaces as possible. While a hypersensitive response to sensitivity testing means that inflammation is present in the periodontal ligament, a normal response does not mean that inflammation is not present since the area of inflammation may have been missed in the testing procedure.



Fig 2-6 *(a)* The percussion test is a simple but highly useful examination method. The handle of a hand instrument is used to tap the teeth in a vertical direction. *(b)* The palpation test assesses tenderness, swelling, fluctuation, and crepitation in underlying tissues.

Palpation also tests for inflammation in the periodontal ligament; however, it is even more limited than the percussion test because it is only really feasible to test the facial surface of the apical part of the root (see Fig 2-6). For this reason, many areas of the root surface are missed by this test. It is likely that a positive palpation test is indicative of a necrotic infected pulp since only a fairly well-established periapical inflammation could cause pain on pressure through the apical facial cortical plate. However, in rare cases, it is possible to have a vital tooth with a hypersensitive palpation test that indicates irreversible pulpitis.

Radiographic Findings

It is not by chance that the radiographic findings are listed so low on the list of diagnostic tests. It is important to remember that a radiograph is a two-dimensional picture of grayscales and thus seriously limited in its diagnostic information. Too often, clinicians rely exclusively on the radiograph for the entire diagnosis!

A tooth with a necrotic pulp and apical periodontitis will probably, though not always, show a periapical/peri-radicular radiolucency. A tooth with reversible pulpitis will not show a periapical radiolucency. A tooth with irreversible pulpitis should not but may (rarely) show a periapical thickening of the lamina dura (Fig 2-7).

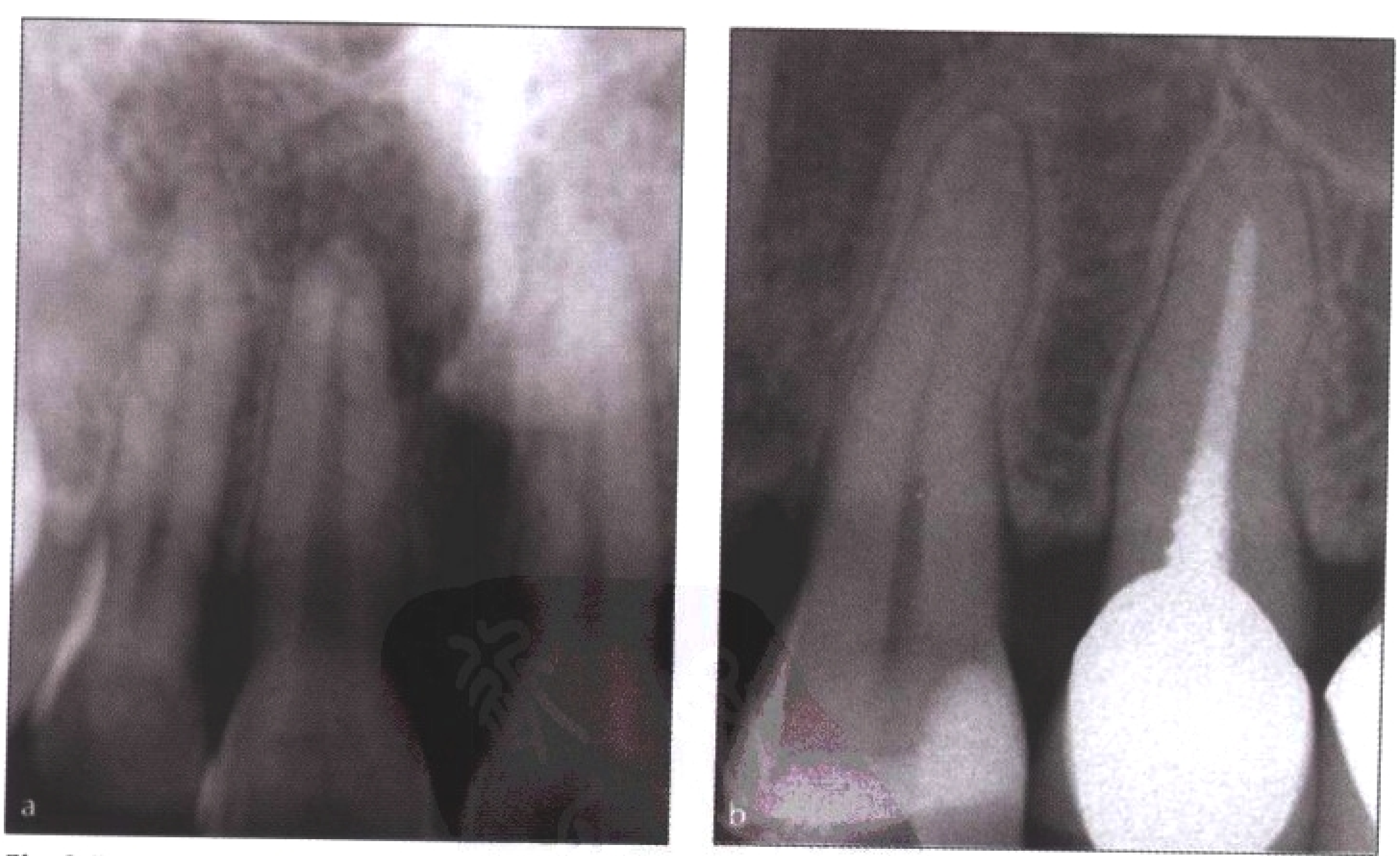


Fig 2-7 Typical radiographic appearance of *(a)* necrotic pulp with chronic apical periodontitis, and *(b)* vital and reversibly inflamed pulp.

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Clinical Findings

After assessing the patient's symptoms and the findings of the diagnostic tests, the clinician should be able to reach a diagnosis and identify which tooth is the culprit. In most cases, the clinical findings will validate the diagnosis. Sometimes, however, the clinical findings may lead the clinician to change the diagnosis.

Caries exposure in a mature tooth

Currently, there is no vital treatment protocol that is consistently effective for the caries- exposed pulp in a mature tooth. Since the aim of treatment is to prevent apical periodontitis, in these cases the most predictable treatment method is pulpectomy under strict aseptic conditions. Therefore, even if symptomatology and diagnostic tests point to a reversibly inflamed pulp, when the clinical exam reveals a caries exposure, the diagnosis would be changed to irreversible pulpitis. Other clinical findings that may change a diagnosis to irreversible pulpitis include a tooth with severe periodontal involvement; an "old" calcified pulp; or a tooth with obvious previous insults.

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3

Root Canal Therapy: Defining and Achieving Success

General Principles

The previous two chapters introduced the different forms of endodontic therapy, including both *vital pulp therapy,* which involves superficial treatment of the pulp or treatment coronal to the root pulp, and *root canal therapy,* which involves treatment of the (vital or nonvital) root canal itself. The latter form of treatment, which applies only to those teeth in the diagnostic categories previously described as *irreversible pulpitis* or *necrotic pulp,* is the subject of this chapter. In certain cases, a tooth with a healthy pulp also may undergo root canal therapy because of restorative or other types of considerations.

Achieving Success

What constitutes success?

As noted earlier, apical periodontitis is the disease process of interest to the clinician performing endodontic therapy. Therefore, the absence of apical periodontitis subsequent to root canal therapy is the only true definition of success. Thus, for a vital tooth in which the aim of treatment was prevention of apical periodontitis, success is the maintenance of a disease-free apical periodontium. For a necrotic tooth in which apical periodontitis was clinically or radiographically evident, however, success is nothing short of eradication of the disease within a reasonable period of time (Fig 3-1).

It is important to emphasize that while time, profit, and postoperative pain are important short-term criteria upon which the patient and dentist may easily evaluate a treatment method, they cannot overshadow the most important long-term criterion for success—the absence of apical periodontitis.



Fig 3-1a Successful endodontic treatment. Despite the poor quality of the root canal treatment on this tooth diagnosed with irreversible pulpitis, the 2-year postoperative radiograph confirms a successful result.



Fig 3-1b Healing is complete at the 2-year postoperative examination in these teeth with apical periodontitis (*a,c* preoperative; *b,d* postoperative).

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Fig 3-2 Results of controlled outcome studies of roots with and without the presence of a radiolucency.

Bacteria and Prognosis

Success with vs without radiolucency

	No lucency	Lucency
Strindberg (1956)	89%	68%
Seltzer et al (1963)	92%	76%
Kerekes & Tornstad (1979)	94%	84%
Sjögren et al (1990)	96%	86%

Fig 3-3 Results of controlled outcome studies of canals that cultured negative (+) or positive (–) before root canal filling.

Bacteria and Prognosis

Success with (+) or (–) culture before root canal filling

	Culture (+)	Culture (–)
Engström et al (1964)	76%	89%
Zeldkow & Ingle (1963)	83%	93%
Oliet & Sorin (1969)	80%	91%
Byström et al (1987)		95%
Sjögren et al (1997)	68%	94%
Bender et al (1964)	No difference	

What are the requirements for success?

In nonvital teeth, apical periodontitis is caused by microbes in the root canal space; in vital teeth, where apical periodontitis is not expected to be found, the root canal is considered uninfected. Thus, it would appear logical that the absence of microbes in the root canal space subsequent to root canal therapy would ensure that apical periodontitis would heal (infected nonvital) or would not develop (vital)–assuming, of course, that the patient has a normal immune system. Controlled outcome studies appear to support this theory. When nonvital teeth that at one time were diagnosed with apical periodontitis and then underwent root canal therapy are compared to vital teeth, the vital teeth have a higher success rate—that is, a larger number demonstrate the absence of apical periodontitis (95% vs 80%) (Fig 3-2).

The explanation for the 15% lower success rate for nonvital teeth is that disinfection of these canals was not effective. Also, in studies where microbial cultures were taken of the root canals before they were filled, those that tested positive to microbial growth had a lower success rate than those that tested negative, which had a success rate consistently above 90% (Fig 3-3).

Of course, it is impossible to culture for all microbes that might be present in the root canal, and therefore many canals that tested negative for microbial growth did in fact contain some microbes. Nonetheless, the microbial threshold below which an

extremely high success rate can be consistently achieved is well established and should be used to measure the effectiveness of any technique chosen by the clinician.

Summary

Fewer microbes in the canal at the time of root filling results in greater success. A treatment approach that results in a consistent (experimental) negative culture will result in success over 90% of the time.

Treatment Phases in Root Canal Therapy

Root canal therapy comprises two phases: the microbial control phase and the filling phase.

Microbial control phase

This phase of therapy is commonly described as *biomechanical cleaning, chemomechanical cleaning*, or *cleaning and shaping*. These terms all relate to the techniques with which the root canal is treated in order to minimize the number of microbes in the root canal space before it is filled. It is important to note that the technique used is not significant, providing that every means possible has been taken to establish a microbe-free canal before the filling phase is started. **Root canal filling should take place only when canal infection is controlled to the maximum degree possible.**

Therefore, the biologic aim of the first phase of root canal therapy is to clear the root canal space of all microbes. This should be accomplished without excessively weakening the root or affecting the tooth's capacity to be restored.

Teeth with vital pulps

Since the root canals of vital teeth are free of microbes at the start of treatment, the treatment principle for this category of teeth is theoretically simple—to ensure that the canal remains free of microbes at the end of treatment. Thus, the method of instrumentation is again not critical provided that adherence to a *strict aseptic technique* is maintained throughout the treatment. If an effective aseptic technique is used and the canal remains free of microbes at the end of instrumentation, it is logical that the prepared canal space and access cavity should be filled with a permanent restoration as soon as possible. Thus, if time allows for optimal attention to detail, both phases of treatment (microbial control and root canal filling) should be performed in a single visit. If possible, the coronal restoration should be placed during this visit as well.

If time is insufficient to complete the procedure in one visit, an intracanal medicament to prevent re-infection can be used in the same manner as for teeth with nonvital infected pulps (see below).

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Teeth with nonvital pulps

Unlike teeth with vital pulps, teeth with nonvital pulps are almost always infected prior to the initiation of treatment. While an aseptic technique is an unwavering requirement for treatment of these teeth as well, a disinfection protocol aimed at the removal of existing canal microbes is required to achieve the aim of the infection control phase of treatment. Disinfection is accomplished via mechanical instrumentation, irrigation with antimicrobial solutions, use of intracanal medicaments between visits, and finally filling of the root canal itself to separate the remaining microbes from the surrounding periodontium, thus promoting healing (Fig 3-5). Even the most technically proficient endodontist is unlikely to consistently remove the optimal number of microbes from the canal through mechanical instrumentation and irrigation alone. Thus, to achieve the aim of the infection control phase of root canal therapy (minimal number of microbes possible), it is recommended that an intracanal medicament be placed into the canal for at least 1 week before the root canal is filled at a second visit.

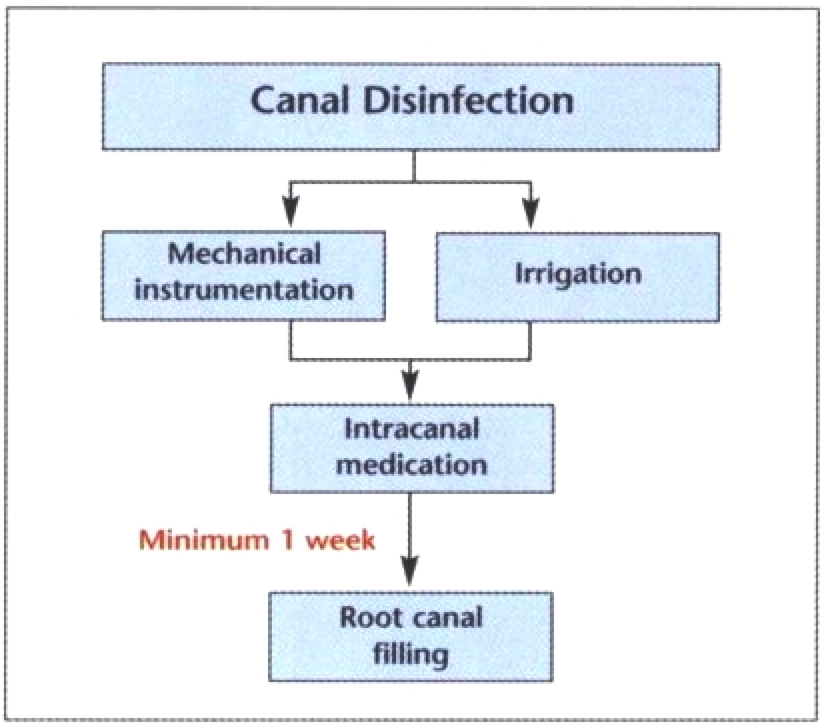


Fig 3-5 Principles of treatment for necrotic (infected) canals.

Stainless steel files and the step-back shape

The traditional technique for instrumenting the root canals of infected teeth is to use stainless steel files with a step-back shape. With this technique, a no. 25 file is used to the working length. This is followed by use of a no. 30 file that is 1 mm shorter than the no. 25 file and then by a no. 35 file that is 1 mm shorter than the no. 30 file. This process is continued at 1-mm increments until the length of the canal is treated from apex to orifice (Fig 3-6). After these "steps" have been created in the canal, a file is used to smooth them out, creating a conical-shaped canal with the narrowest part at the apical foramen, gradually increasing in diameter toward the canal orifice.

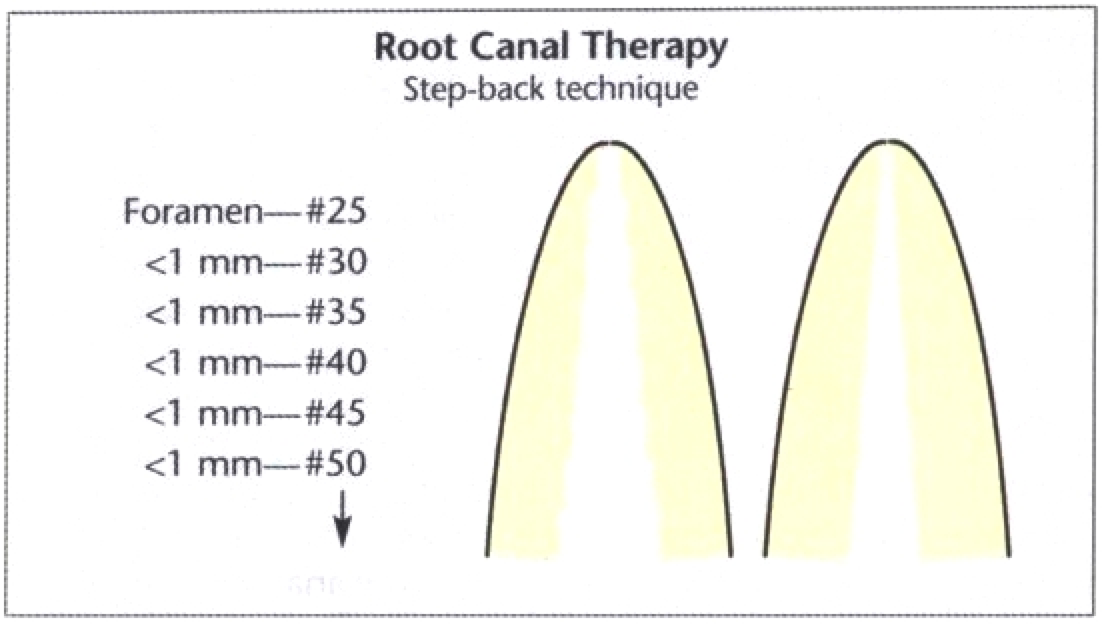


Fig 3-6 Step-back technique.

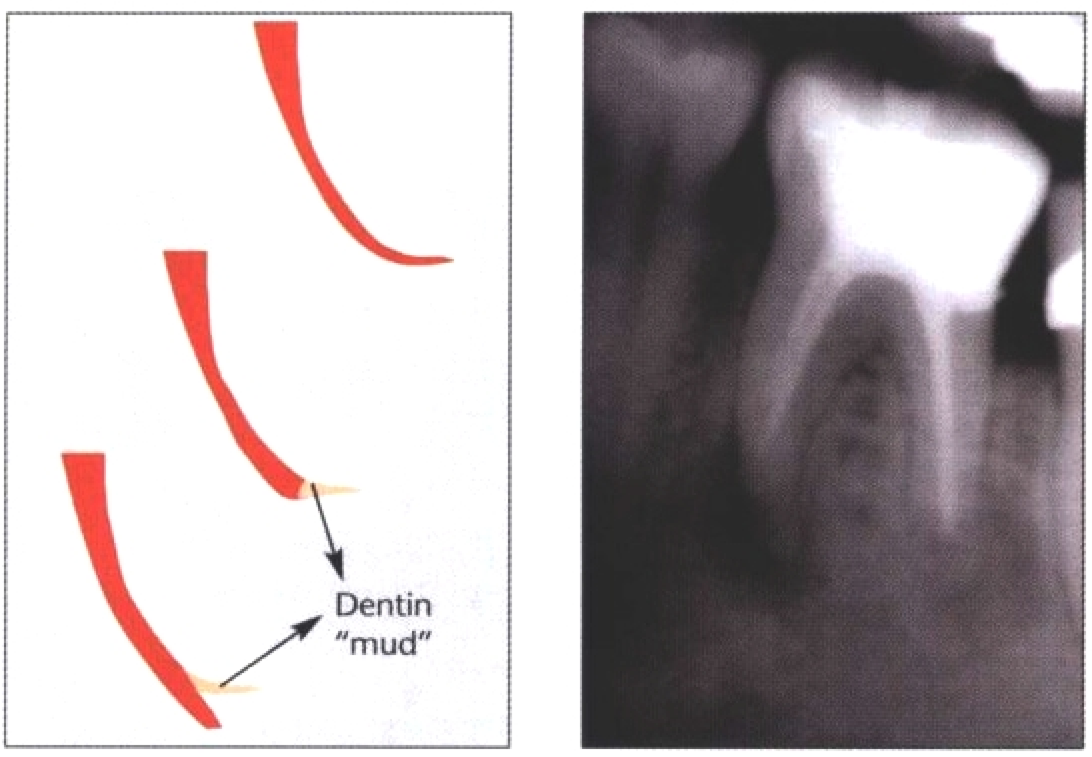


Fig 3-7 Effect of packing dentinal debris apically. The larger files are pushed away from the true canal, causing straightening or even perforation.

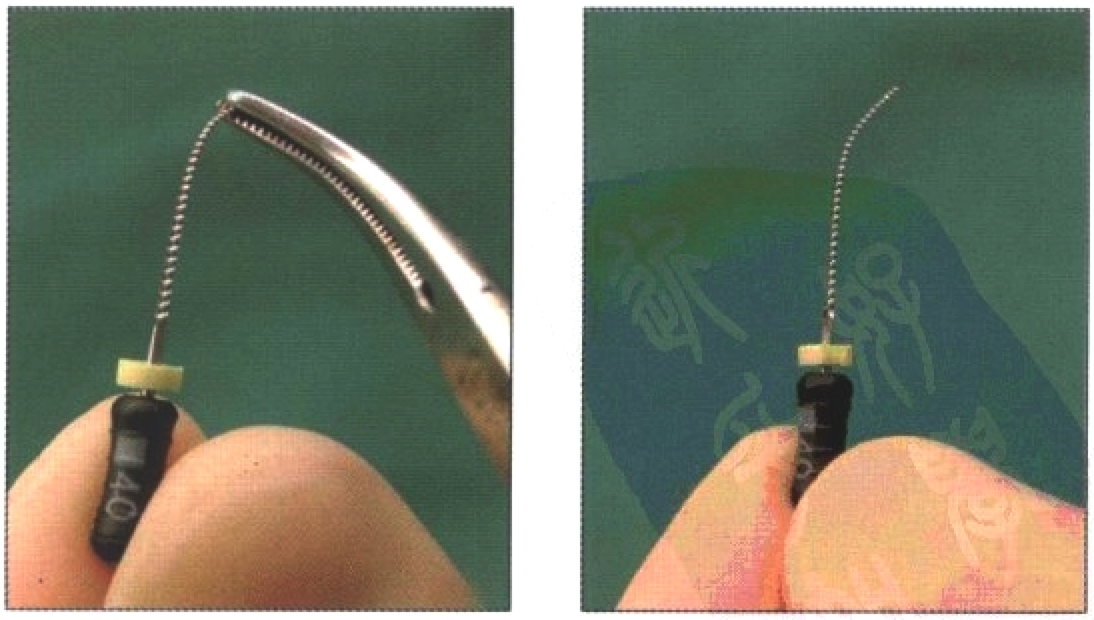


Fig 3-8 Stainless steel file no. 40 bent with a hemostat. The file is not flexible and therefore stays in its bent position.

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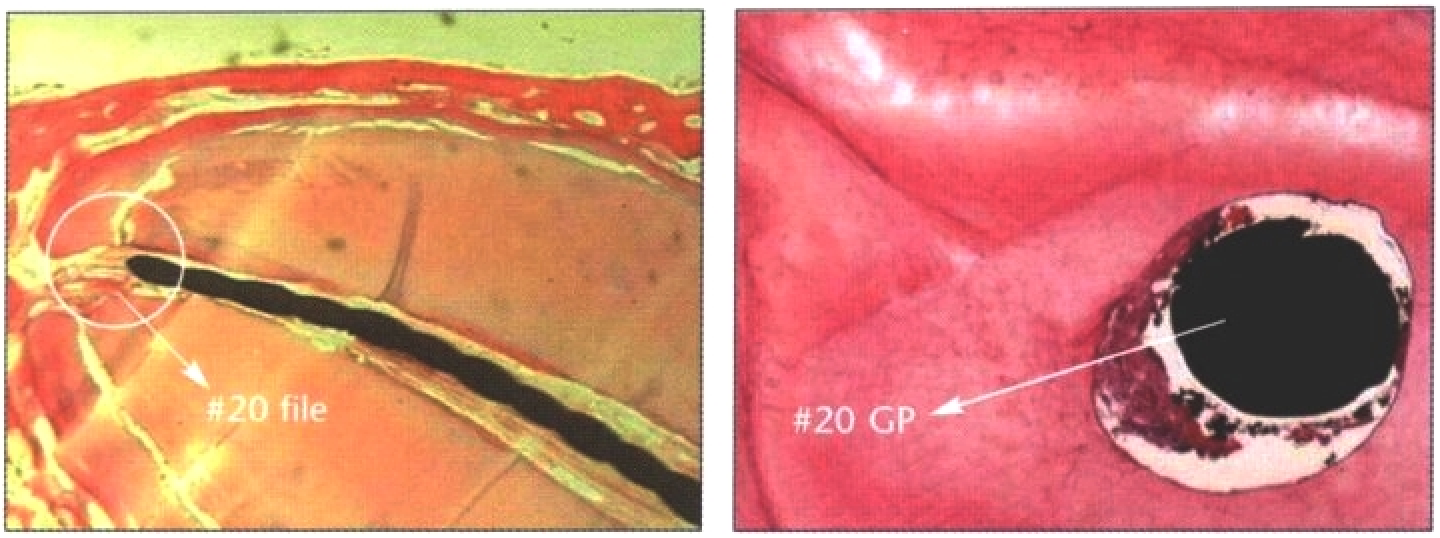


Fig 3-9 Step-back technique. Note the difference between the size of the true canal and that of a no. 20 file *(left)* or gutta-percha point *(right)*, even in the smallest canals. (Courtesy of Dr Richard Walton.)

While the step-back technique is safe in terms of procedural errors, it fails in the most critical aspect of the microbial control phase of endodontics: The size of the file at the apex is too small to adequately reduce the number of microbes to minimal levels. For this reason, the success rate for the treatment of teeth with infected canals is approximately 15% lower than that for vital uninfected canals (Fig 3-7).

Stainless steel files are precurved, but they become progressively less flexible as they become larger in size (Fig 3-8). This lack of flexibility in the larger files has been cited as the main cause of most incidents of apical blocking, straightening, creation of elbows, and strip perforations. In the authors' opinion, however, it is not the inflexibility of stainless steel files but rather the apex-to-crown approach to instrumentation that ultimately leads to most root canal failures. With this approach, as described below, a small file is maneuvered close to the apical foramen in an unprepared canal. The file now contacts the entire wall of the canal from apex to orifice. Instrumentation is initiated, producing a relatively large amount of dentinal debris throughout the length of the canal. In order to keep the canal unblocked and ready for the next larger instrument, all the dentin produced by the previous file must first be removed from the canal. In addition, this removal of dentin should be achieved coronally, not apically, in order to avoid blockage of the canal and the procedural problems already described. It is thus easy to see how instrumentation that begins with an ISO size 10 file and progresses to size no. 40 or no. 50 will lead to blockage of the apex with dentinal debris, causing shortening or straightening of the canal space (Fig 3-9). This is not the result of a lack of flexibility in the instrument, but rather the cumulative effect of using the 7th (no. 40) or 9th (no. 50) file in the sequence to remove all debris coronally. **The step-back shape is thus ineffective in achieving the biologic aim of the infection control phase of root canal therapy.**

Modified step-back shape

To overcome the limitations of the step-back shape of instrumentation, the modified step-back shape was devised. In this instrumentation technique, the step-back shape is accomplished first, since it is a relatively safe method of instrumentation in terms of procedural errors. After using a no. 25 file at the working length, the apical third of the canal is instrumented to larger sizes more appropriate for adequate cleaning of the canal (Fig 3-10). Thus, a size no. 30 is placed to working length and the sizes sequentially increased to larger apical third sizes. The use of larger-sized files is possi-

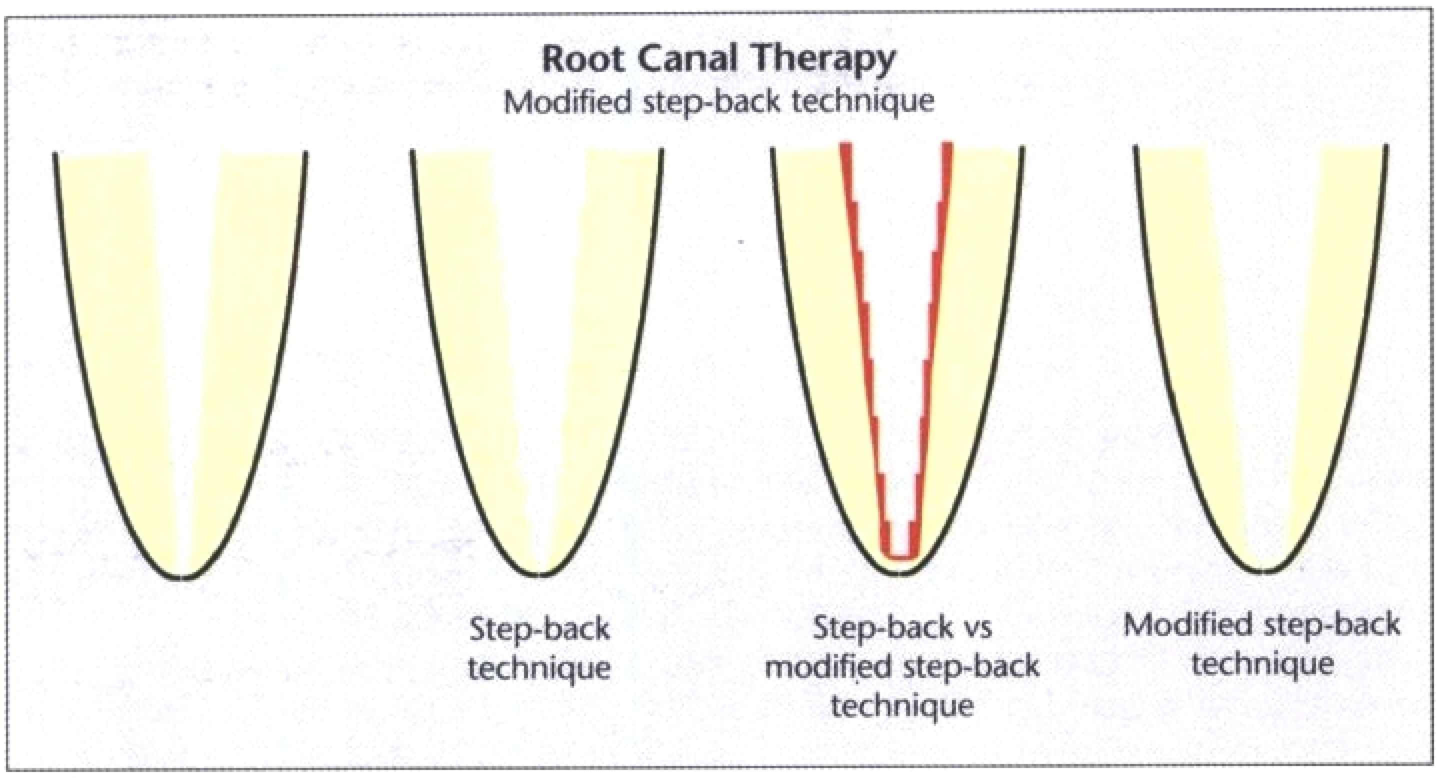


Fig 3-10 Modified step-back technique. The step-back shape is performed first. The apical third is then widened to biologically acceptable sizes.

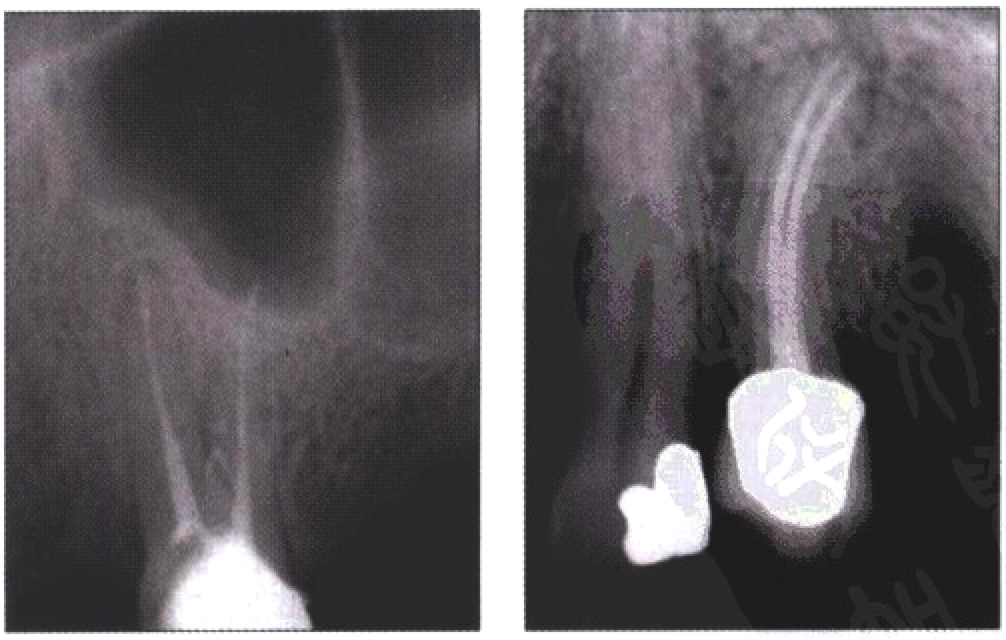


Fig 3-11 Radiographic appearance of teeth undergoing a step-back *(left)* versus a modified step-back technique *(right)*.

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ble with this modified technique because of the space already created by the traditional step-back technique in the coronal two thirds of the canal. This space allows the larger files to be placed to working length, binding only the apical 3 or 4 mm of the canal. Thus, the dentinal debris produced by filing is much less than if the file contacted the entire canal, and there is adequate space for the produced dentin to easily move coronally (rather than apically). The modified step-back technique using stainless steel files will allow the practitioner to achieve acceptable microbial control in a more predictable fashion than the traditional step-back technique (Fig 3-11).

Crown-down technique with nickel titanium files

The past several years have witnessed a number of revolutionary changes in the instrumentation used for the microbial control phase of root canal therapy. The most significant change is the use of nickel titanium (NiTi) metal in endodontic files. NiTi files are extremely flexible and elastic. Moreover, they can be flexed under tension and then will "spring back" to their original size once the tension is released (Fig 3-12). Thus, they are easily able to follow curves in canals that were thought to be impossible with stainless steel files. The one disadvantage of this metal is its point of plasticity—that is, the point at which it stretches and the point at which it fractures are very close together. This means that if the metal is stressed, it can break without adequate warning to the clinician. However, if used carefully and according to instructions, fracture of these instruments is a rare occurrence.

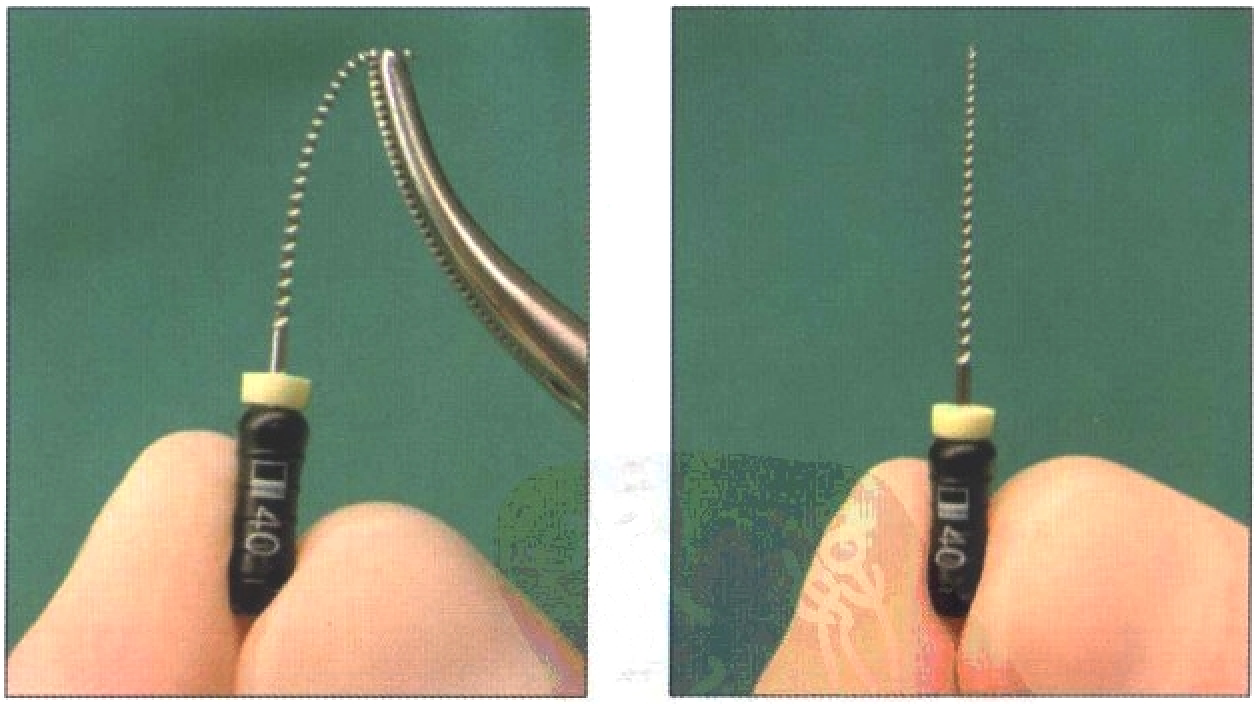


Fig 3-12 NiTi no. 40 bent with a hemostat. Because the file is highly flexible, it springs back to its original position.

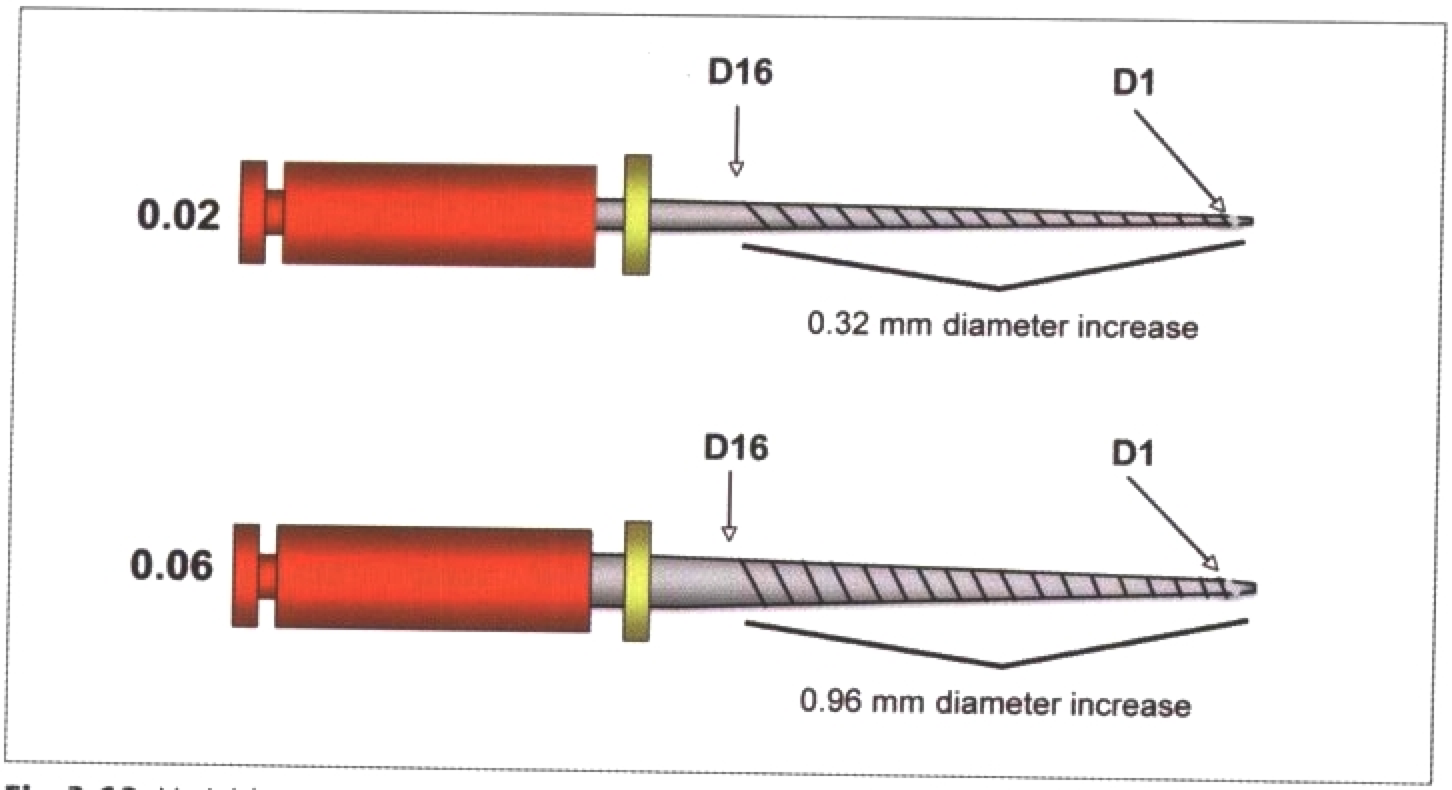


Fig 3-13 Variable tapers.

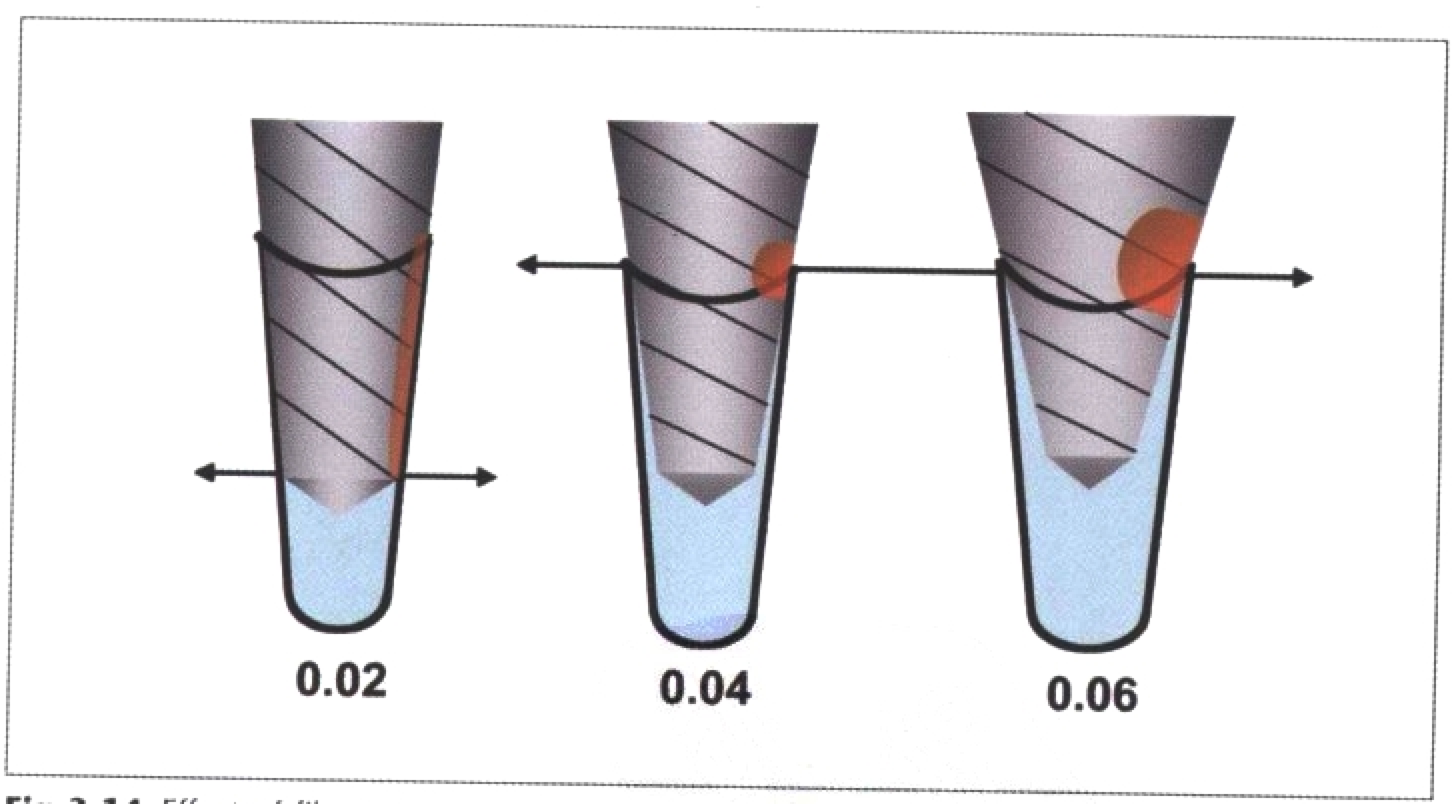


Fig 3-14 Effect of file taper on surface contact on the canal wall. Note that lower tapers leave less space apically and thus more debris can be forced in an apical direction, whereas higher tapers will cut more dentin coronal to the point of contact.

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Another change in the file design within the last few years is the variability of the cutting length and taper of the files (Fig 3-13). Unlike stainless steel files—which were required to have a cutting edge of 16 mm independent of the overall length of the file and a taper increase of 0.02 mm/mm of cutting edge (0.32 mm total)—modern files have varying cutting edges and tapers ranging from 0.02 mm all the way to 1.2 mm/mm of cutting edge. A disadvantage of the larger tapered files is that the deeper they are placed in the canal, the more (unnecessary) coronal dentin is removed. A wedge shape is created, making the tooth more susceptible to fracture (Fig 3-14). It is therefore important to use the highly tapered files only in the coronal aspect of the canals and to decrease the taper as the file penetrates deeper into the canal.

As a result of the varying taper of the files, it is now possible to instrument root canals in a crown-to-apex direction, known as the *crown-down technique*, rather than in the step-back technique previously described. With the crown-down technique, a file is chosen with a taper that will allow it to loosely fit into the natural canal and then bind at the orifice, about 4 mm into the canal, when the taper becomes larger than that of the canal. When binding occurs, the file is rotated by hand or engine and the instrument moved apically in the canal. The file is advanced in 1-mm segments down the canal until the apical 3 to 4 mm of the instrument binds in the natural canal. At this point, instrumentation with this file should stop because too much of the file is binding, making breakage a distinct possibility and forcing dentinal debris apically. At this point, the next *smaller-sized* file, possibly with a smaller taper, is chosen to advance the file deeper into the canal. Because the smaller file is chosen, the requirement that the apical part of the file is loose in the canal is re-established and the file can safely proceed down the canal in 1-mm segments with little chance of breakage or blockout by dentinal debris. Thus, the working length can be achieved with relatively few files.

However, it cannot be stressed enough that while the working length at size no. 25 is much easier to achieve with NiTi files in a crown-down technique than with stainless steel files, at this point all that will have been achieved is the step-back shape, which we have already demonstrated to be inadequate for the microbial control phase of root canal therapy! Therefore, an additional step, similar to that required for the modified step-back shape, must be performed in the apical third of the canal. This step also is easier to perform with the new generation files. Indeed, sizes that are even larger than those obtainable using stainless steel files and the modified step-back shape can be safely achieved.

Summary

Nickel titanium files with variable tapers have revolutionized the way root canal therapy is performed. The initial phase of treatment is accomplished in a crown-to-apex direction, which creates space and allows for adequate cleaning of the apical part of the canal. The files are then used to adequately clean the apical third of the canal to sizes that will ensure the lowest possible microbial count before root canal filling.

Filling phase

The filling phase begins when the clinician is satisfied that the microbial count in the canal is at its lowest point. As stated earlier, this usually takes place during the first visit (time permitting) in the treatment of a vital tooth or following treatment using an intracanal medication in an infected necrotic tooth. The filling phase includes the root filling *and* the top or coronal filling. As its name implies, the aim of this phase is to fill the space created in the root and crown during the microbial control phase. If the space is optimally filled, remaining bacteria will not be able to communicate with the periradicular tissues, periapical exudates will not nourish remaining bacteria, and oral microorganisms will be prevented from repopulating the root space.

Suggested Reading

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4

Root Canal Therapy: Clinical Procedure

Throughout this chapter, we assume that the tooth in question has been diagnosed and that it requires root canal therapy.

Estimated Working Length

It is essential for the clinician to establish an accurate estimate of the working length of the tooth before initiating treatment. This estimate is based on the preoperative radiograph, which should *always* be taken just prior to commencing treatment. In order for the radiograph to represent as accurately as possible the size and length of the tooth, the film must be positioned parallel to the tooth in question (Fig 4-1).



Fig 4-1 If placed correctly, the paralleling device will produce an image that fairly accurately represents the size and the length of the tooth.

A paralleling device will greatly simplify this task, especially in the maxilla; however, the clinician must bear in mind that this device ensures only that the tooth is parallel to the x-ray head and the x-ray film. The challenge for the clinician is to place the device so that the tooth is parallel *between* the head and film. In the mandible, it is much easier to ensure that the film is parallel to the tooth. However, the patient will need to lift the tongue while the film is positioned so that it can slip down parallel to the tooth (Fig 4-2).

The maxilla poses a much greater challenge. In many cases, the palate is too flat to allow the film to be positioned properly without causing it to bend and conform to the shape of the palate (Fig 4-3). Care should be taken to prevent this from occurring. Often the film must be placed toward the midline of the palate, and in these cases it is useful to place a spacer, such as a cotton roll, between the film and the tooth (Fig 4-4).

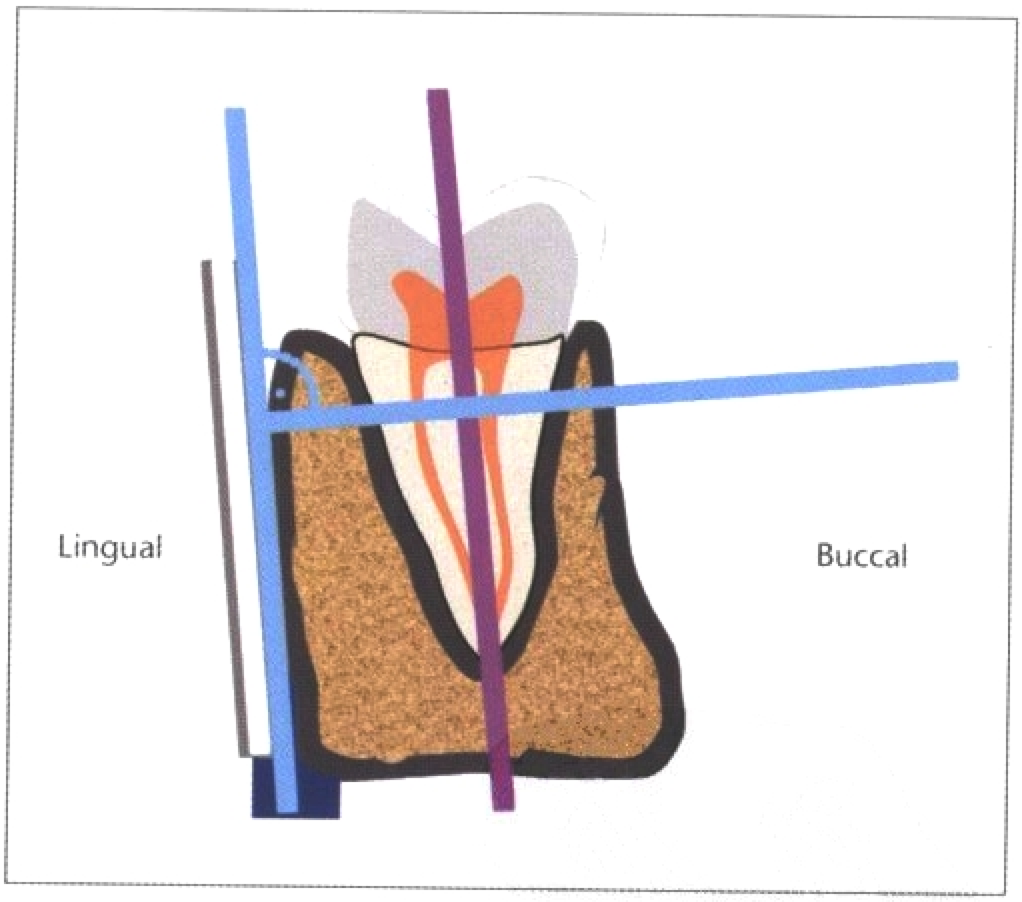


Fig 4-2 Placement of film parallel to tooth in the mandible. The parallel film-to-tooth orientation will produce a radiograph that accurately represents the length of the tooth.

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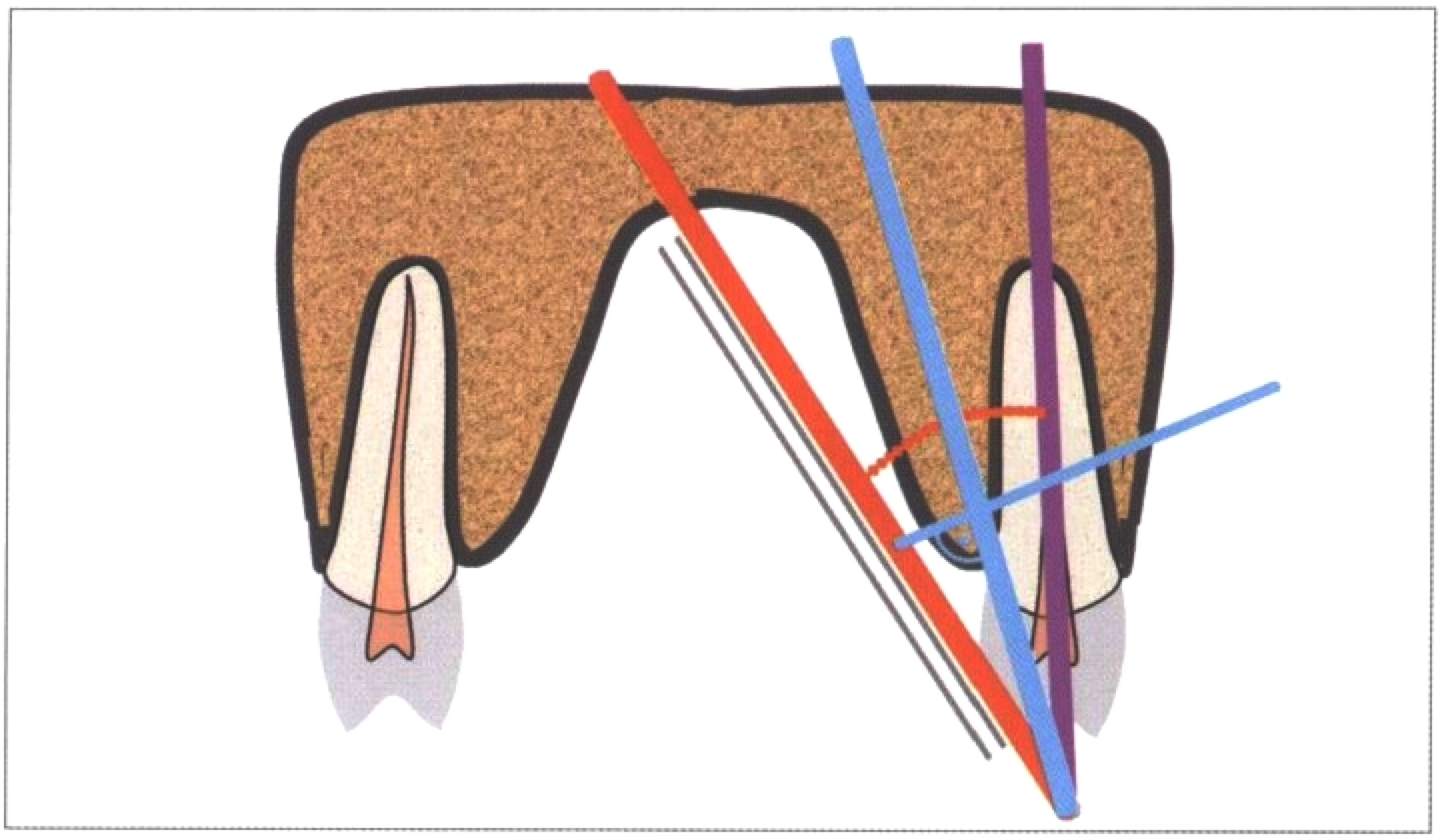


Fig 4-3 Bisecting angle technique with paralleling device. The shape of the palate makes placement of the film close to the maxillary tooth difficult. This difficulty must be taken into account when calculating the estimated working length on the radiograph.

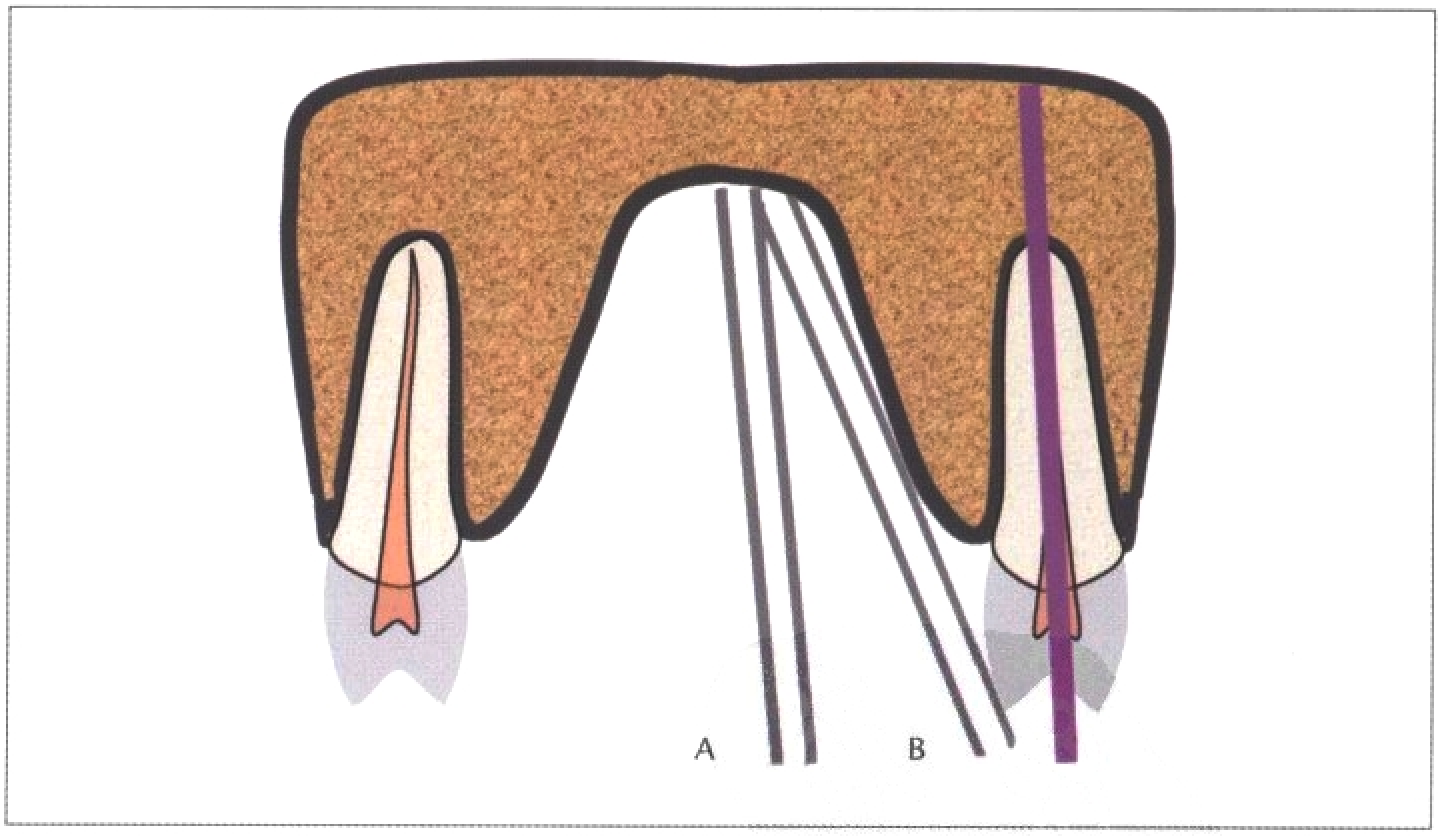


Fig 4-4 Placing the film deeper into the palate (A) will make it more parallel to the tooth. It is beneficial to place an object such as a cotton role between the film and the crown of the tooth to maintain its position while the radiograph is taken.

Once the parallel radiograph has been taken, a ruler or digital measuring device can be used to measure the tooth's radiographic image from its most coronal aspect to the apical tip of the root (Fig 4-5). Although this measurement is only an estimate—a fact the clinician should always remember—it will nonetheless allow the coronal two thirds of the root to be safely treated before the accurate working length is taken for instrumentation of the apical third.

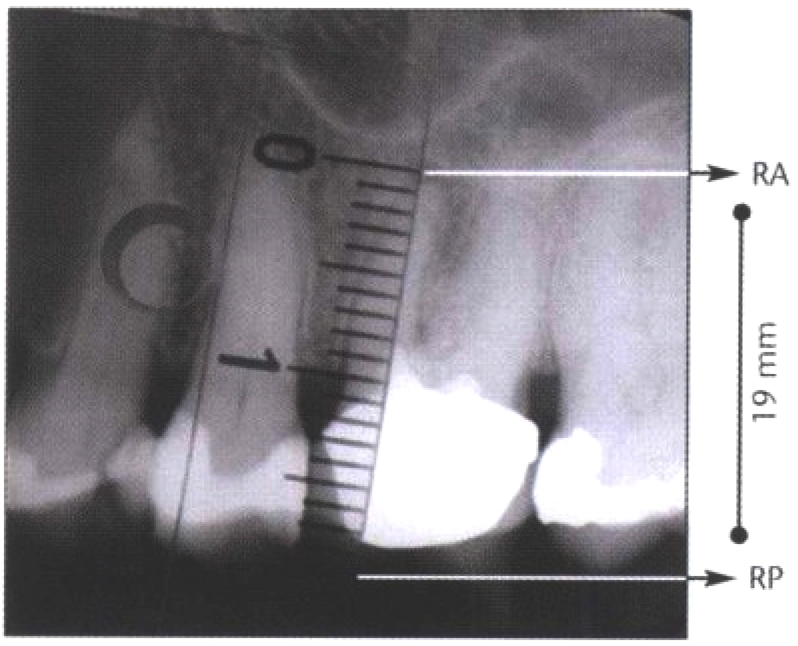


Fig 4-5a A ruler can be used to estimate the working length on a parallel preoperative radiograph (RA, radiographic apex; RP, reference point).

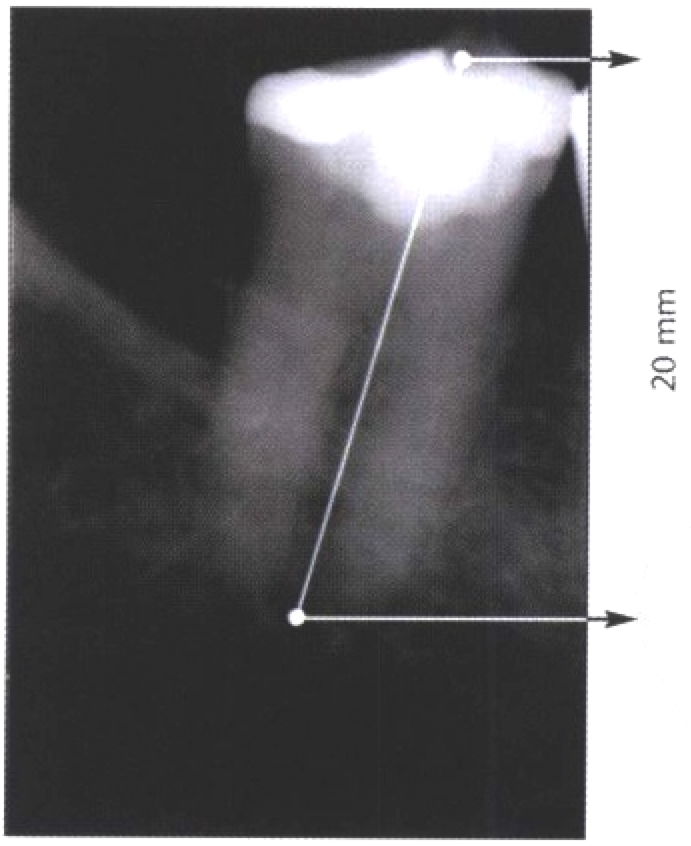


Fig 4-5b Measurement of the estimated working length on a parallel digital radiograph.

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Access Cavities

Correct access is a key to successful root canal therapy. Straight line access cannot be compromised. With nickel titanium (NiTi) files, proper access is even more important because unlike stainless steel files, these files cannot be bent to facilitate entry into the orifice of the canal, nor can they easily be pushed against a particular wall of the canal for fear of breakage.

It is beyond the scope of this manual to review the anatomy and list the number of canals in each tooth. It should suffice to say that adequate treatment is impossible without a thorough knowledge of root anatomy (Fig 4-6). Remember that you will never find more canals than you are looking for.

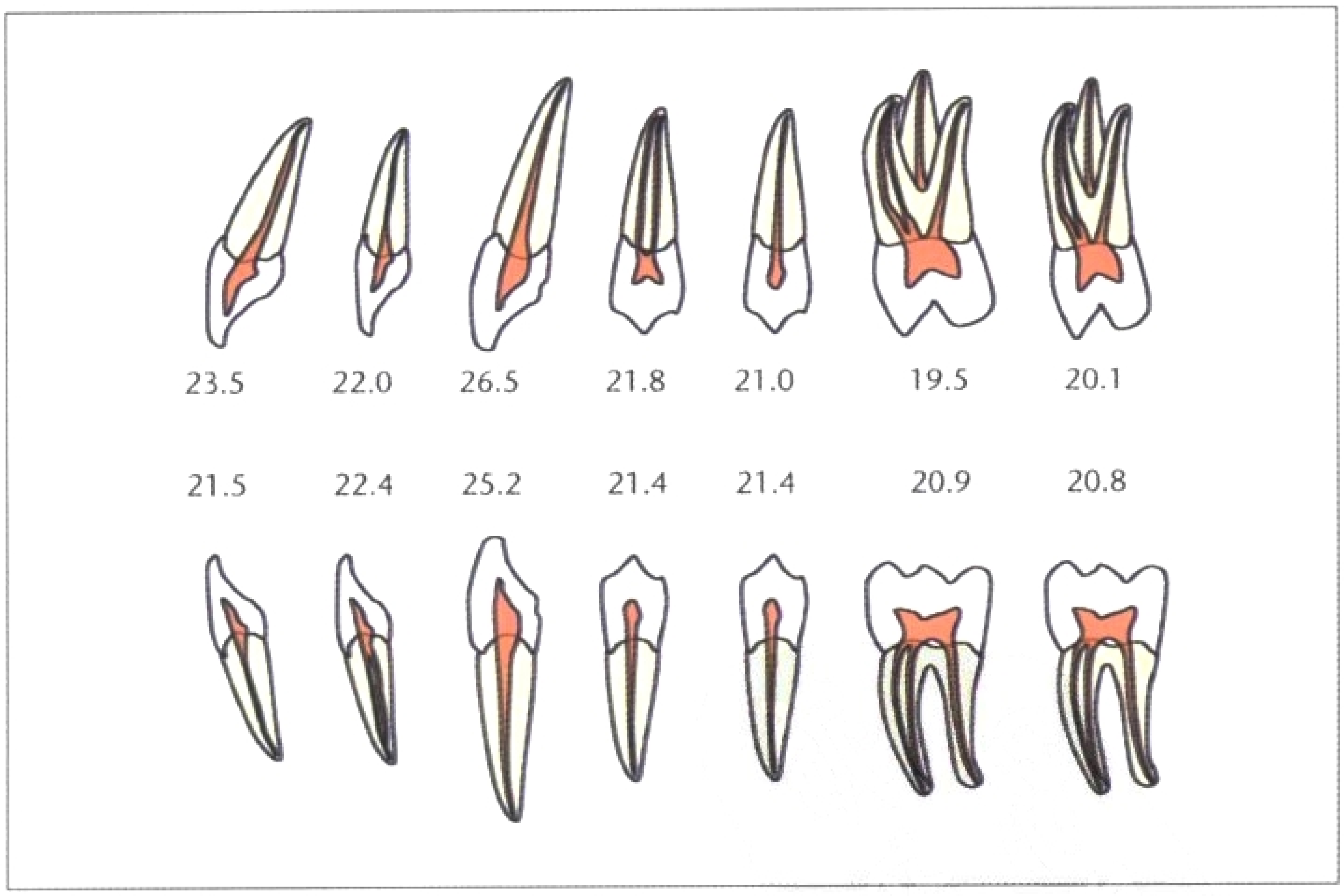


Fig 4-6a Average length (mm) of all teeth.

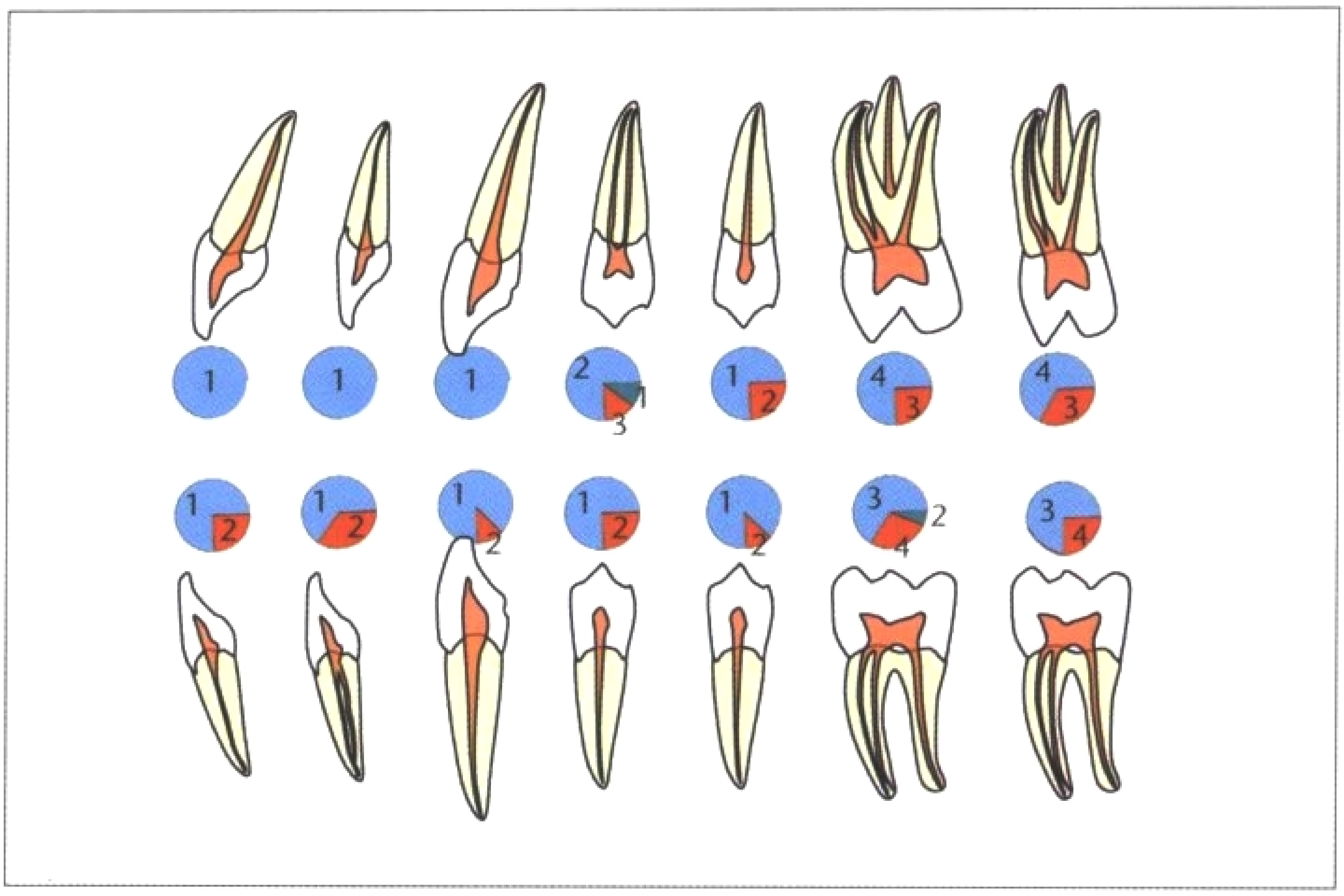


Fig 4-6b Number (frequency) of canals found in each tooth type.

Presented below are several tips to guide readers in creating access cavities that offer the best chance to adequately instrument the root canal.

1. The pulp chamber is always located at the center of the tooth; its outline is a miniature of the outer border of the tooth **at the level of the cementoenamel junction (CEJ)** (Fig 4-7).

   When starting the access cavity, the outer border of the tooth at the CEJ should be clearly within view; thus, if one aims for the middle of the CEJ, the pulp chamber should always be located. Once the roof of the chamber is penetrated, the entire roof can be removed by following the shape of the outer border of the tooth at the CEJ. From a practical point of view, the authors recommend making the access into the pulp chamber before the rubber dam is placed, since this will afford the best view of the CEJ. When the access is complete and all caries and leaky restorations have been removed, the rubber dam can be placed and steps can be taken to ensure an aseptic environment.

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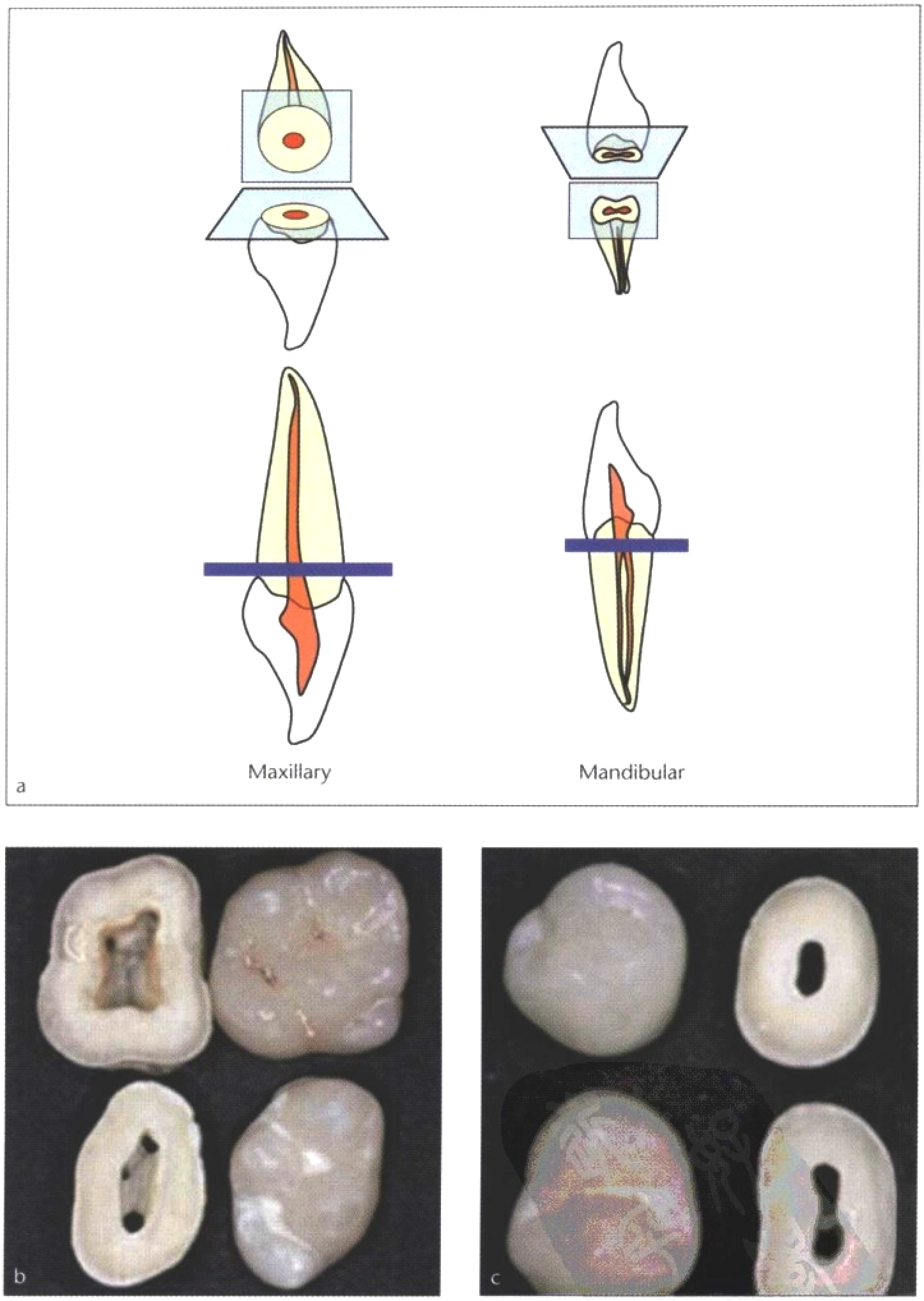


Fig 4-7 The shape of the pulp chamber mirrors the outline shape of the root at the level of the cementoenamel junction (CEJ).

2. The orifices of the canals are always located at the junction between the darker chamber floor and the lighter chamber walls and usually at the vertex of the dark-floor angle (Fig 4-8).

   Only when the junction between the dark floor and lighter wall can be easily distinguished is the access adequate. If this junction cannot be seen, it is an indication that the entire roof of the chamber has not been removed. In this case, the access must be enlarged by removal of the entire roof of the chamber. Once the access is adequately enlarged, it will be possible to use an endodontic explorer to probe for the canal orifices at the vertex of the chamber floor angles. The floor of the chamber should be drilled only when there is evidence that the canal orifices are calcified. In the vast majority of cases, it will be possible to find the orifices with an endodontic probe.
3. In teeth with multiple canals, the orifices are symmetrical to each other (Fig 4-9). If an orifice is found on one side of an imaginary line drawn mesiodistal through the floor of the chamber, one should expect to find another orifice equidistant on the opposite side of the line. If the orifice is located exactly on this line, it is likely to be the only orifice present, and it is not necessary to look for another.

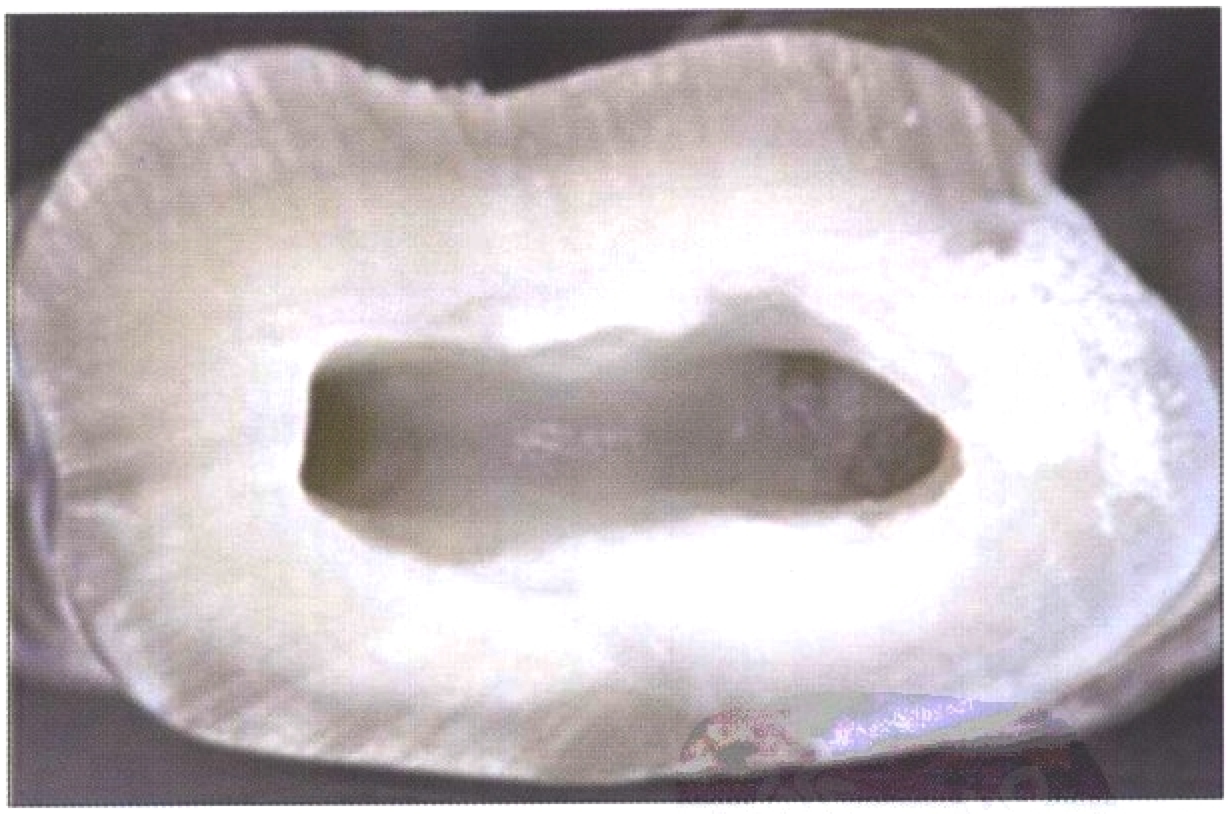


Fig 4-8 Occlusal view of an access cavity. The light walls meet the dark floor; the canal orifices are located at the angles of the dark floor. The access cavity is adequate when the junction between the dark floor and the light walls can be visualized.

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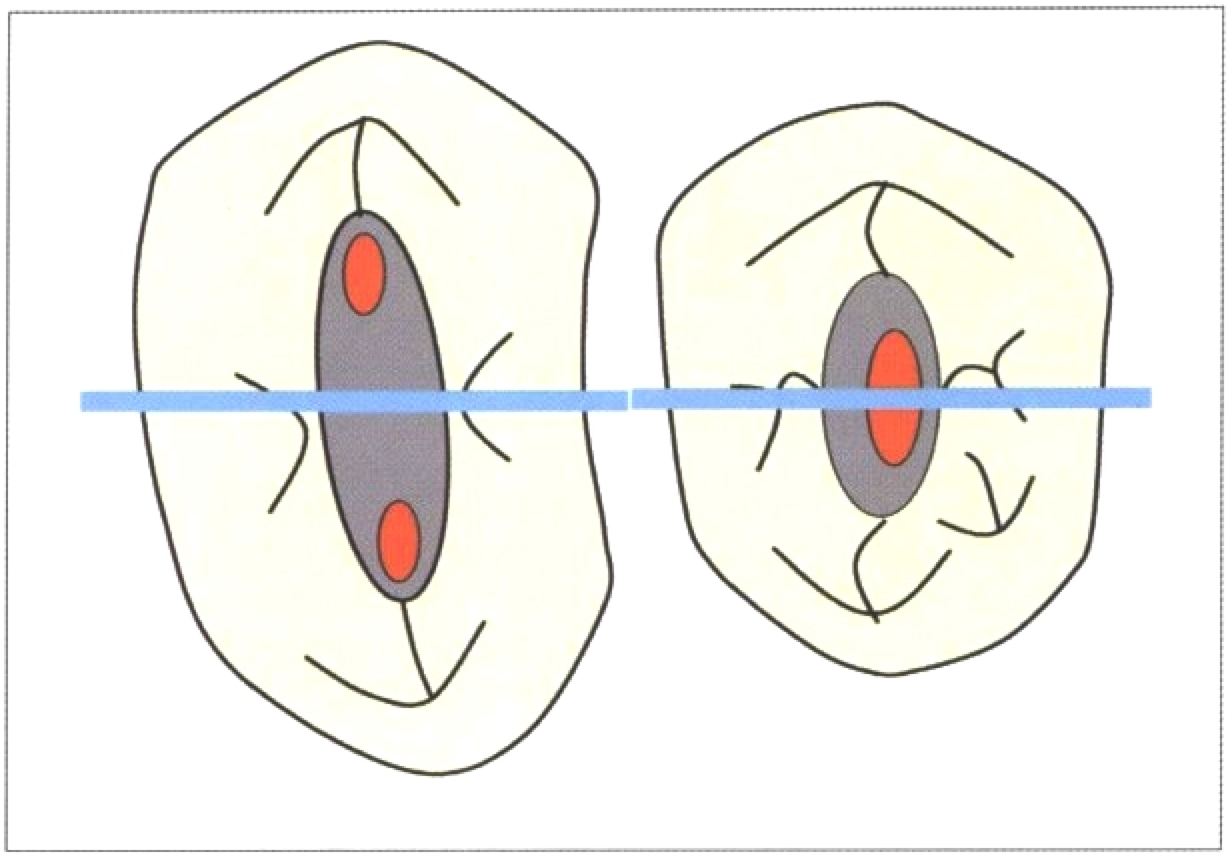




Fig 4-9 The canal orifices are symmetrical to each other.

Aseptic Technique

Since the key to successful root canal treatment is controlling the microbial flora in the root canal before it is filled, it is critically important to apply a technique that does not result in contamination of the canal during treatment. Asepsis is the key!

While the importance of asepsis is simple enough to understand in theory, practicing strict asepsis is one of the most difficult tasks to learn, primarily because microbes are invisible to the naked eye. Some basic rules will help the practitioner and assistant develop a more effective aseptic technique:

1. Divide the treatment into "dirty" and "clean" stages. The dirty stage is performed before the rubber dam is placed and involves creating the access opening and removing ALL caries and suspect restorations. Do not compromise in performing these tasks. It is impossible to maintain an aseptic environment in the tooth if any caries remains. Moreover, if the tooth is nonrestorable, it is important to find this out before the root treatment begins (Fig 4-10).

   Once the caries and leaky restorations have been removed and the tooth is deemed restorable, the rubber dam is placed and the circumference sealed from saliva (Fig 4-11).

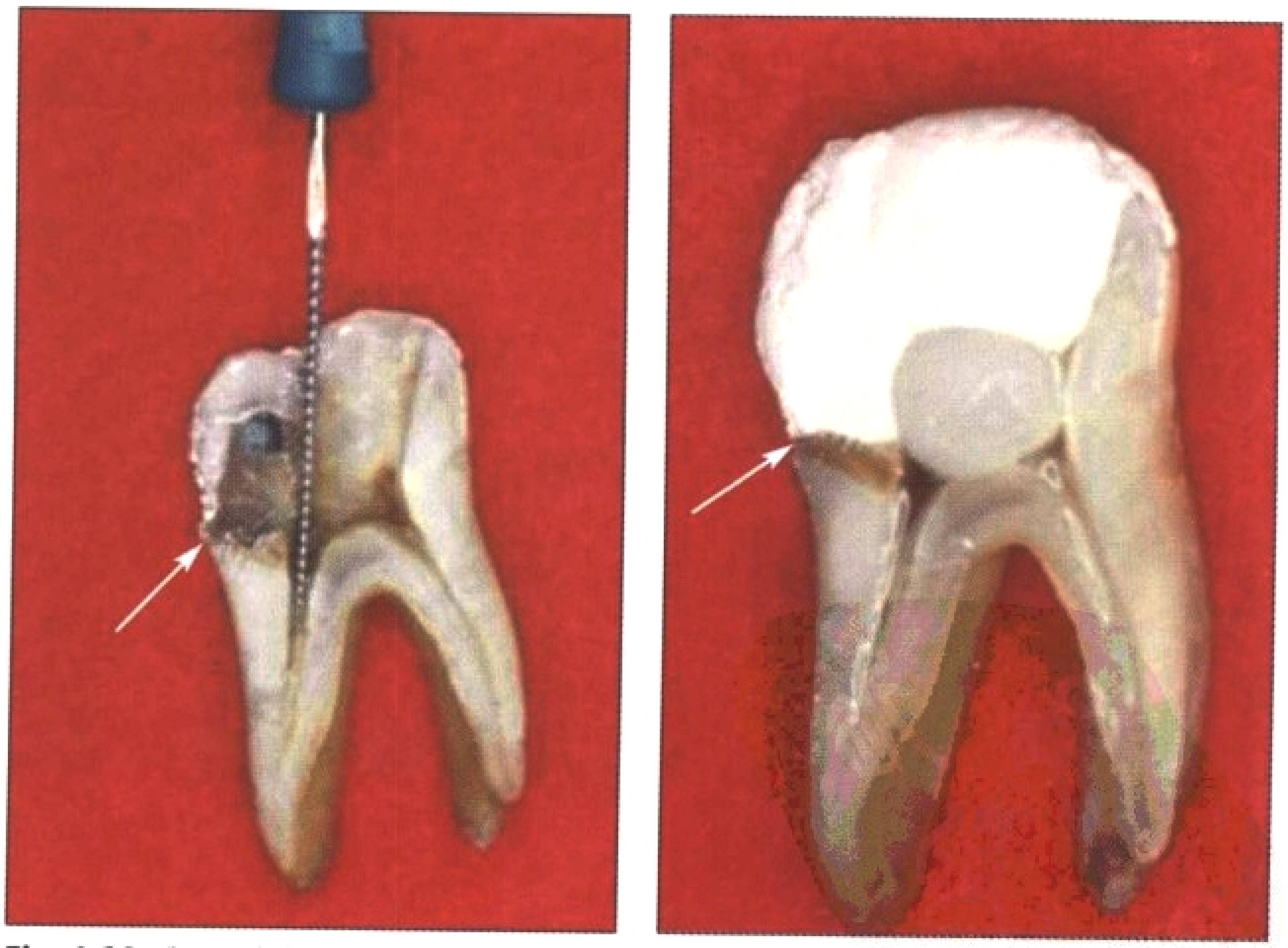


Fig 4-10 Caries left in a tooth during endodontic treatment or after placement of the temporary filling. The primary goal of root canal therapy and microbial control can never be achieved under these circumstances.

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2. The access and approximately 2 cm of rubber dam are then disinfected (Fig 4-12). Chlorhexidine and betadine are common medicaments used for this purpose. From this point on, all instruments that enter the canal must be sterile.

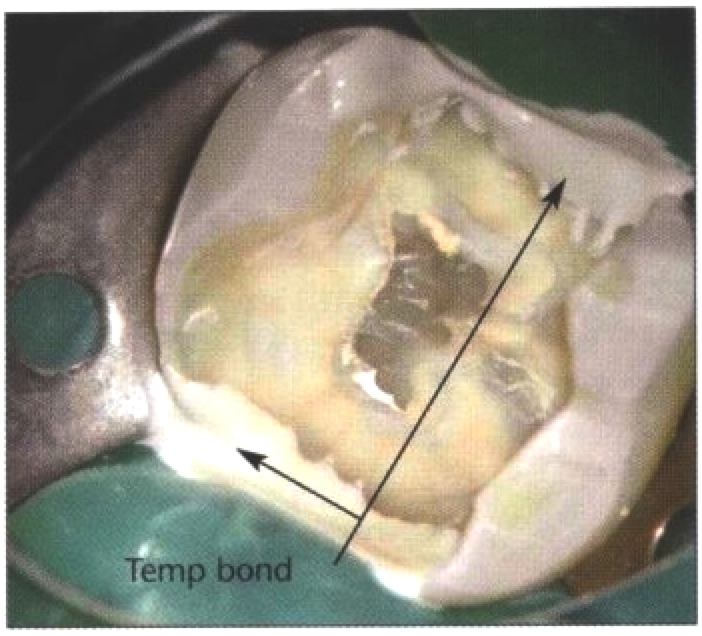


Fig 4-11 Removal of caries and leaky restorations and sealing of the rubber dam against saliva contamination.

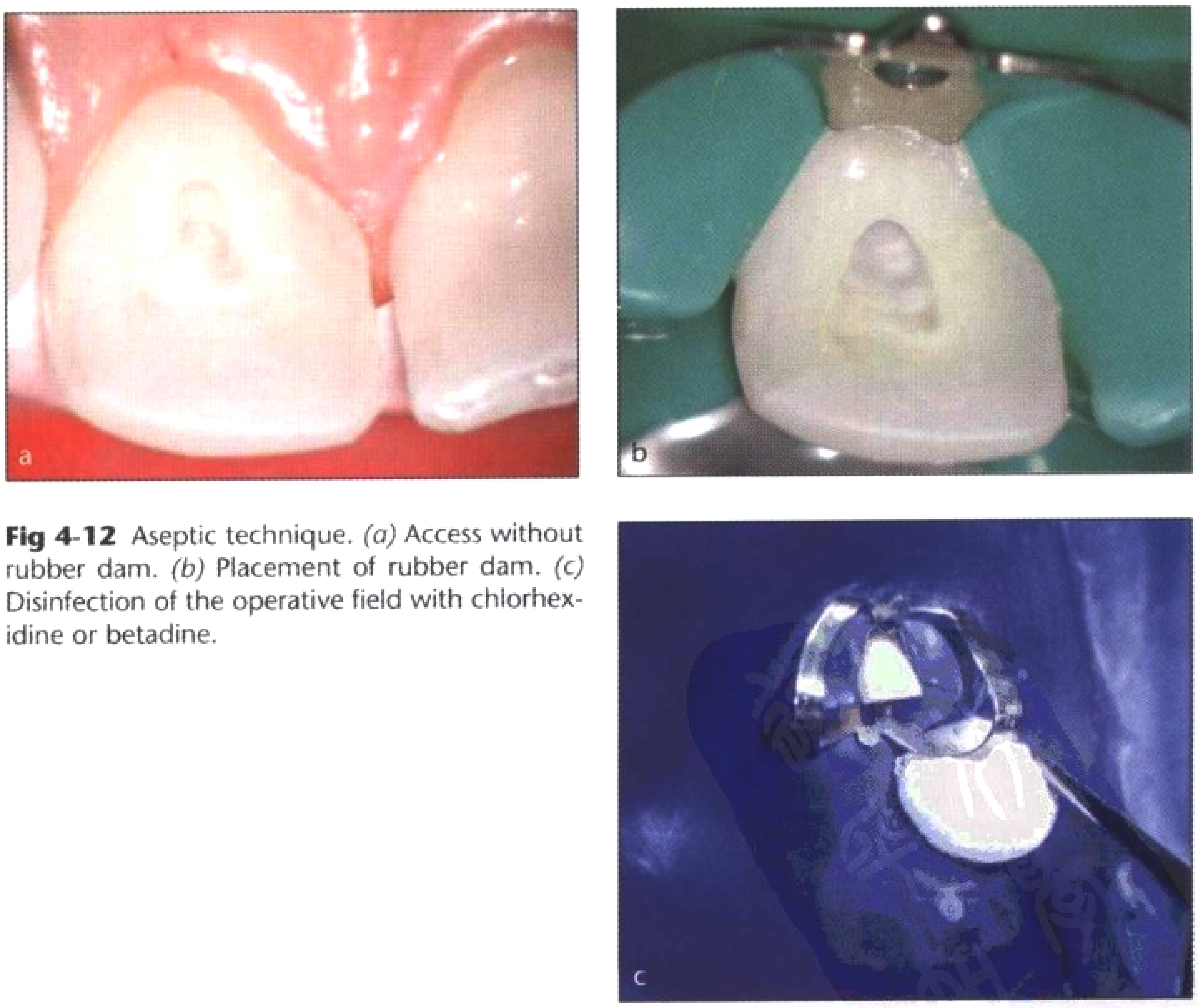


Fig 4-12 Aseptic technique. *(a)* Access without rubber dam. *(b)* Placement of rubber dam. *(c)* Disinfection of the operative field with chlorhexidine or betadine.

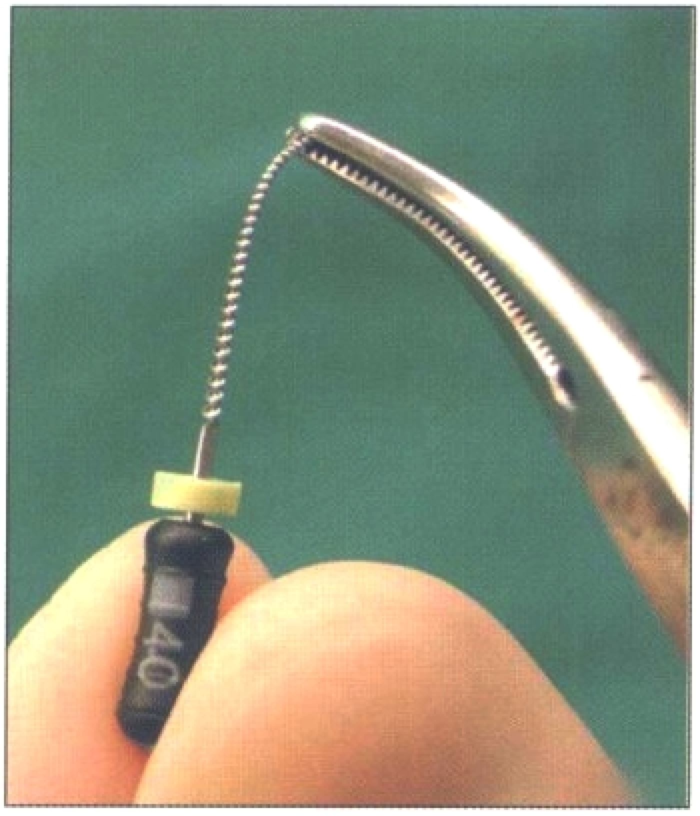
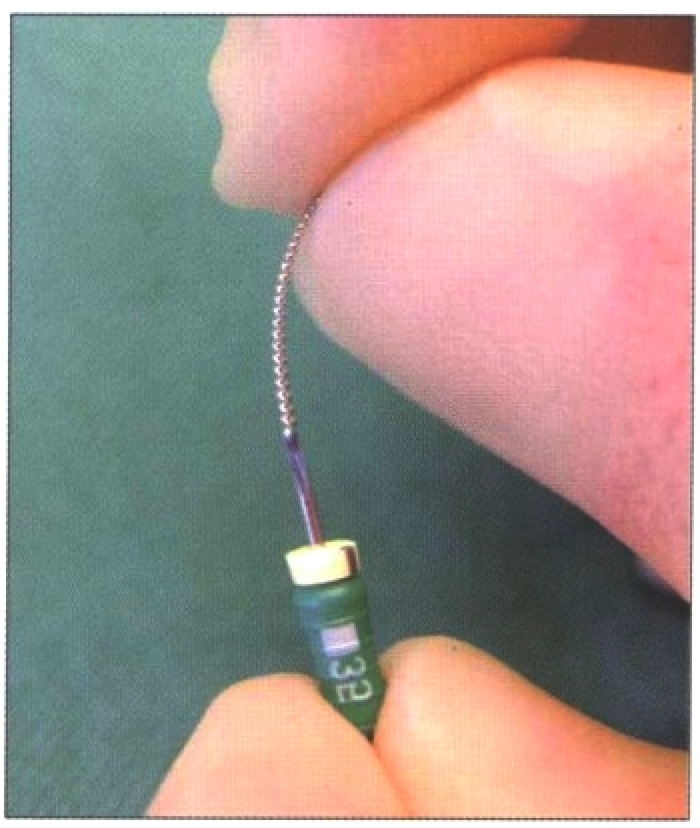




Fig 4-13a Maintaining asepsis by using a sterile hemostat to curve a file *(left)*. When the file is placed in a blood agar plate *(above)*, no growth of microbes occurs.



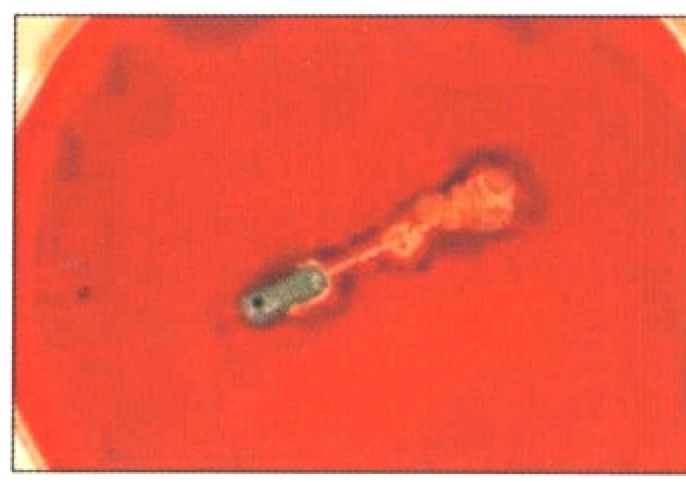


Fig 4-13b When a gloved finger is used to curve the file *(left)*, microbes grow around it in the blood agar plate *(above)*.

3. Divide the work area itself into "dirty" and "clean" areas to maintain sterility. Never touch the files with your hands (Fig 4-13); instead, use sterile cotton pliers or a similar type of instrument.
4. Keep all sterile (clean) instruments to the left and all used (dirty) instruments to the right. A used instrument on the right side must not be reused until it has been disinfected and replaced on the left side (Fig 4-14).

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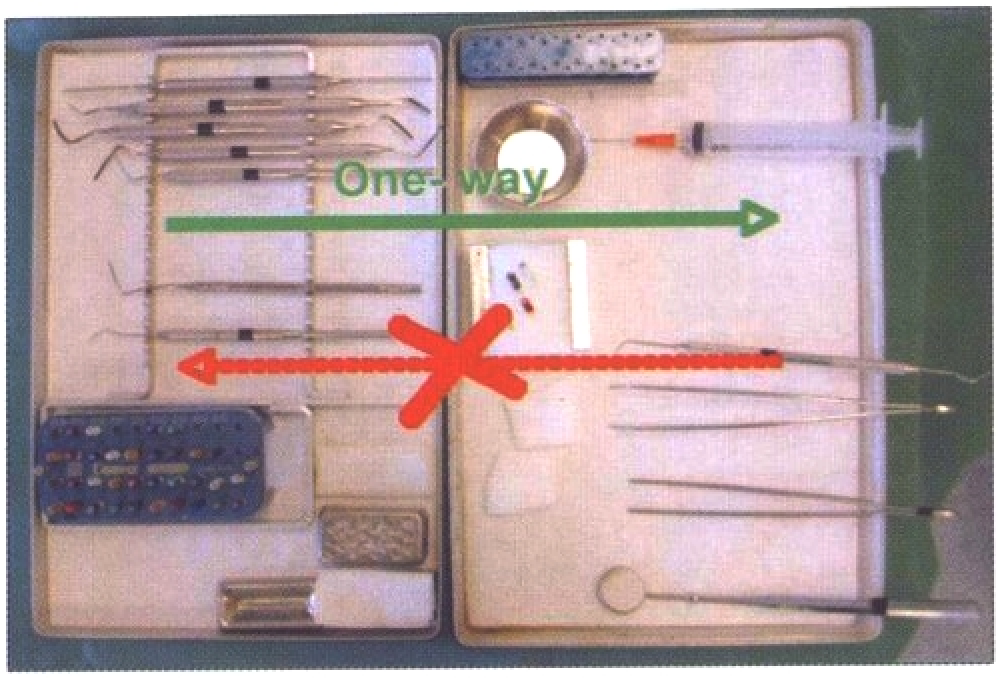


Fig 4-14 To maintain asepsis, all used (dirty) instruments are placed on the right side of the tray. Instruments must be wiped off and sterilized before they can be put back on the left (clean) side of the tray.

Working Length

Even to this day, the length to which the canal should be instrumented remains a controversial topic of discussion. Most clinicians agree that the apical constriction or narrowest point, often referred to as the *minor foramen,* does not correspond to the tip of the root (Fig 4-15). Thus, if the file reaches the radiographic apex, it is very likely to have penetrated the foramen (Fig 4-16). Histologic studies show that the constriction is situated on average about 0.5 mm coronal to the root apex. In addition, outcome studies on root canal treatment conclude that in a tooth with a vital pretreatment diagnosis, the best results are obtained when the canal is instrumented and filled 1 to 2 mm coronal to the radiographic apex.

On the other hand, in a tooth diagnosed with necrotic pulp and apical periodontitis, the best results are expected when the tooth is filled 0.5 to 1 mm coronal to the radiographic apex (Fig 4-17). Nearly all studies show that for both diagnostic categories, a long core fill offers the worst prognosis! It is also important to establish a working length for instrumentation that is at, or short of, the canal minor foramen for root canal filling purposes. By creating a stop at the apex, pressure can be used to place the filling material and to fill the entire canal. In this way, the material can be moved in a lateral direction, thus conforming to the shape of the true canal (Fig 4-18). Filling a canal without a mechanical stop at the apex would be analogous to filling a mesio- or disto-occlusal cavity preparation without having a wedge on the matrix. Material would "leak" into the periodontal ligament, leaving the cavity unfilled and susceptible to re-infection.

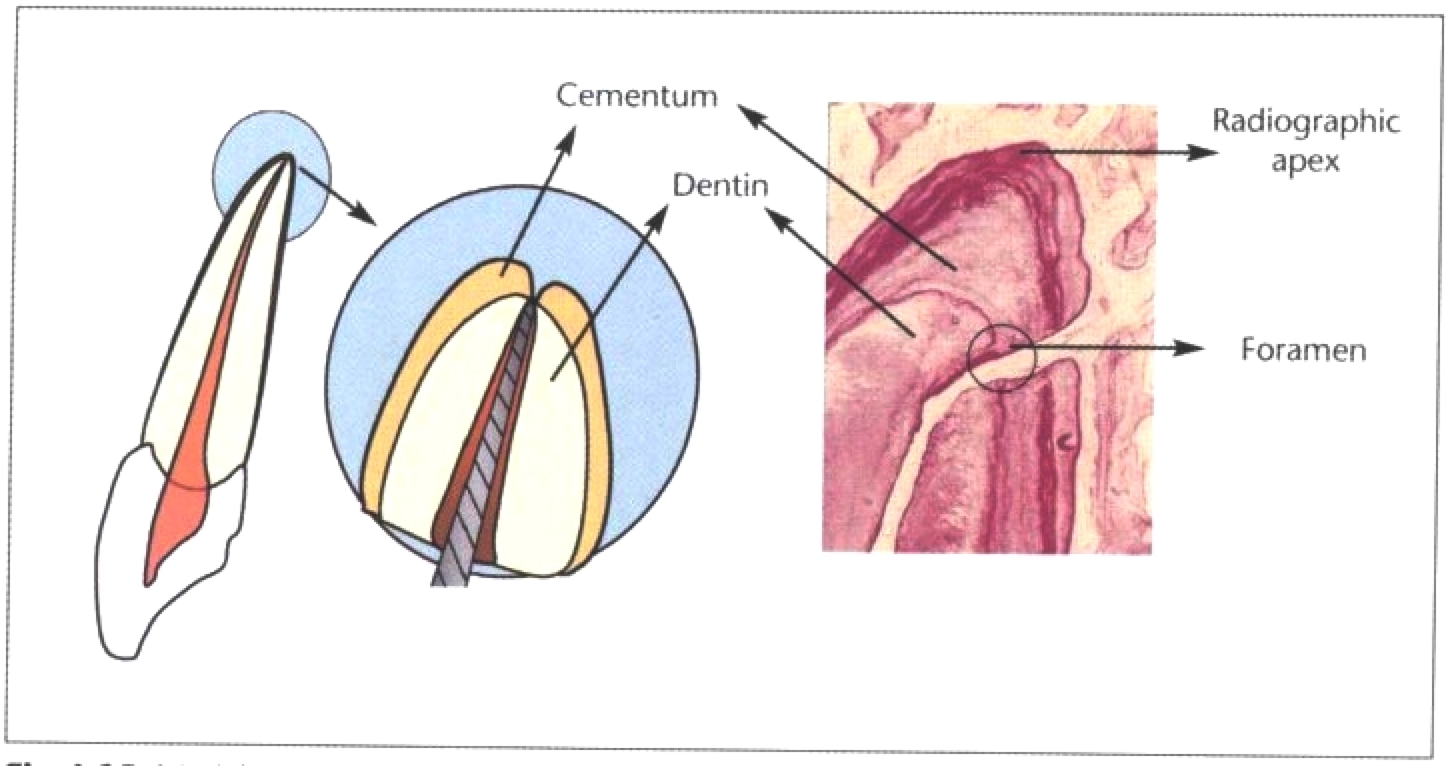


Fig 4-15 Mesial view of an anterior tooth. The "natural" constriction in the apical area is 0.5 to 1.0 mm from the radiographic apex.

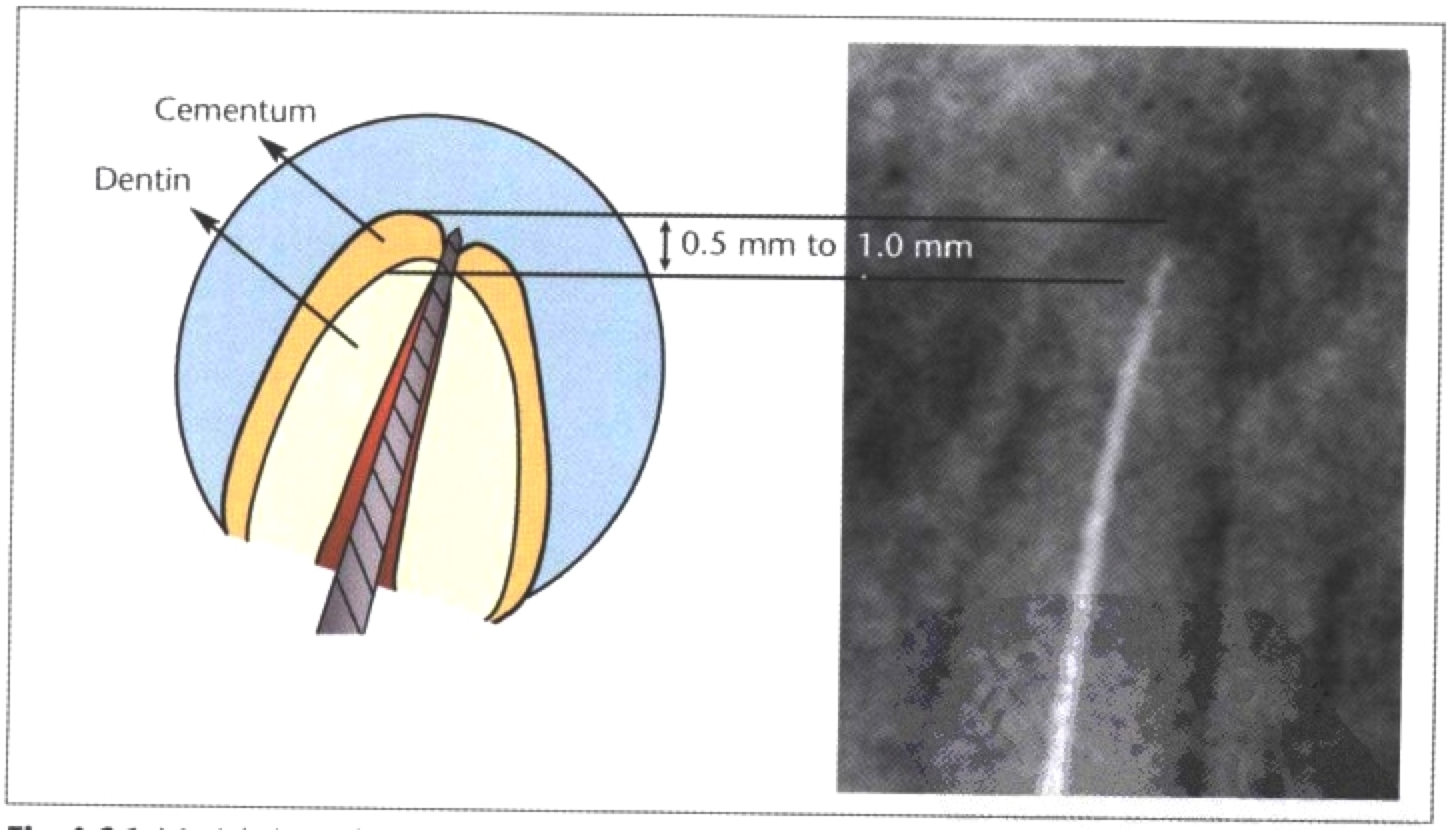


Fig 4-16 Mesial view of an anterior tooth. A radiograph that shows the file at the apex of the root probably means that it has penetrated the apical constriction.

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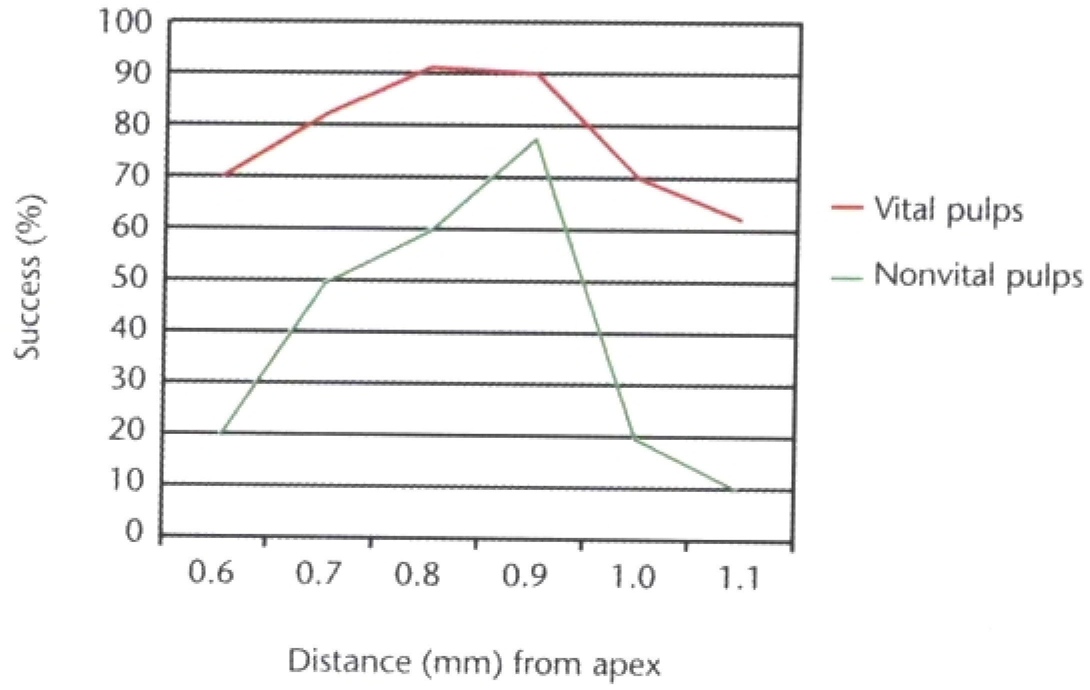
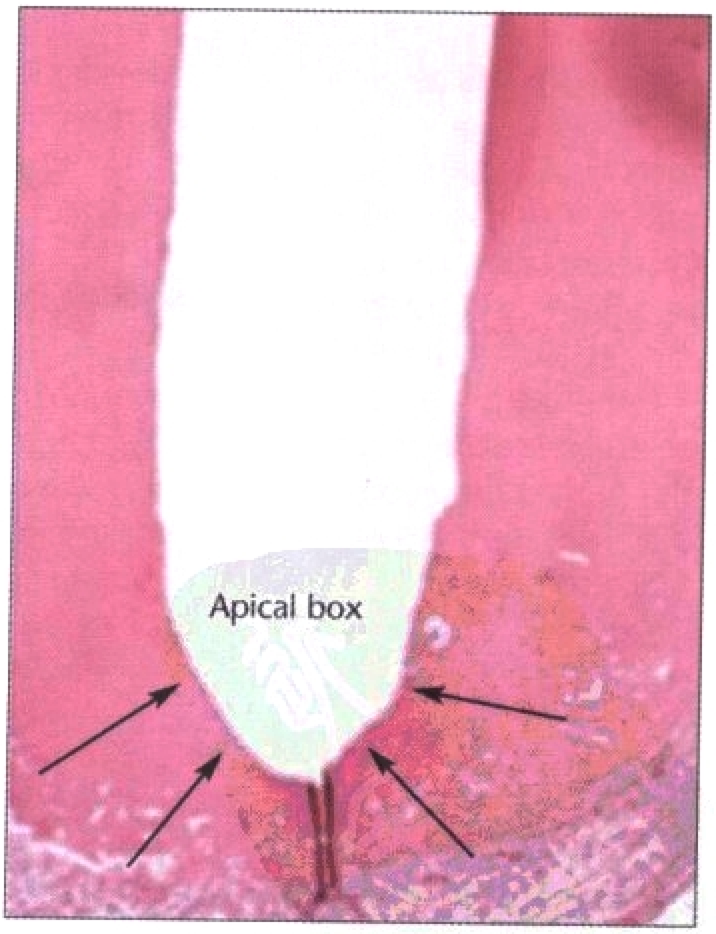


Fig 4-17 Success rates for teeth with (pretreatment) vital and nonvital pulps. For both categories, the highest success rates are achieved when the teeth are filled short of the radiographic apex. Particularly in nonvital teeth, the success rate decreases when the core filling is long.

Fig 4-18 The apical box within dentin creates a matrix that enables optimal filling of the space.



At this stage of treatment, it is not necessary to know the precise working length since the length of the canal will change slightly once the coronal two thirds is instrumented. Therefore, a preliminary working length should be established 1 mm from the radiographic measure at this stage of treatment. If the clinician is confident that the preoperative radiograph was taken in a parallel fashion (see Estimated Working Length, above), it is even possible to dispense with the working length radiograph and take an exact length radiograph after the coronal two thirds of the canal have been prepared.

Root Canal Instrumentation

Once all caries and leaky restorations have been removed, straight line access has been attained, and an aseptic environment ensured through the use of a well-sealed rubber dam and surface disinfectant, it is time to instrument the root canals. This is the most important aspect of microbial control and is performed in conjunction with the use of antimicrobial irrigating solutions.

Root canal exploration with a stainless steel no. 10 file is performed prior to taking the working length radiograph. It is important to understand that NiTi instruments merely follow canals; they do not find them. The clinician must first locate a canal and create a patent pathway to the canal foramen, and the NiTi instruments will then easily follow this path. The canals are explored using "stiff" stainless steel files (no. 8, no. 10, no. 15, or no. 20). In the authors' experience, the no. 10 file will most often conform to the estimated working length of the canal. An exploratory curve is placed in the apical 2 to 3 mm of the file (Fig 4-19), allowing the tip to explore a different direction in the canal with a slight twist of the file handle. Using this "watch-winding" motion, the file should "slip and slide" down the canal. If it encounters an obstacle, the file can be retracted slightly, the handle twisted to change the orientation of the tip, and the file can again be advanced to continue exploring the canal (Fig 4-20). Extreme patience and care must be exercised by the clinician when attempting to negotiate an obstacle in the canal. If the file is forced against an obstacle, a ledge is created that will be very difficult to bypass (Fig 4-21).

If the file remains loose in the canal as it nears the estimated working length, larger stainless steel files should be placed to the foramen until a size is reached that cannot easily be placed to the estimated working length. Increasing the size of the "natural" canal now reduces the number of NiTi instruments that will be required later to make the apical third of the canal smaller in diameter than the rest of the canal (see Chapter 3, General Principles). Once the file nears the estimated working length, the crown-down technique can be employed using the rotary instruments.

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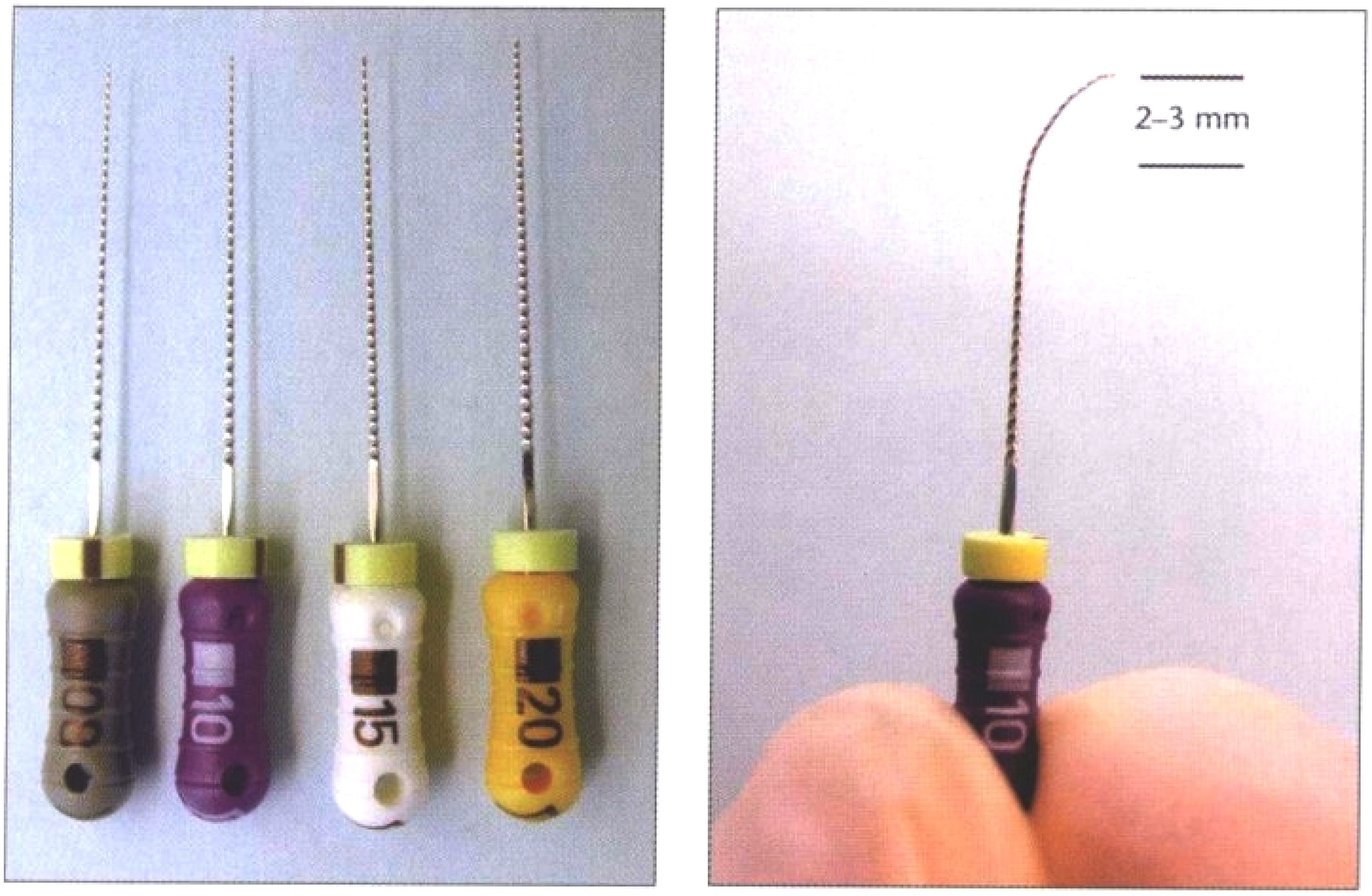
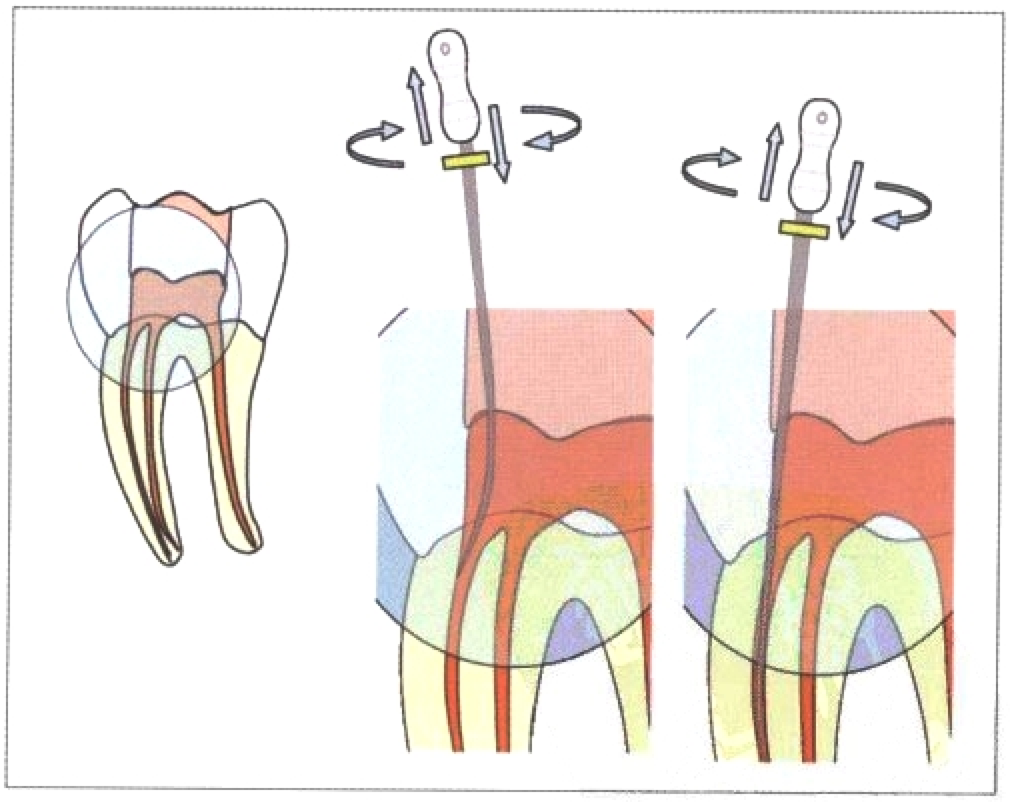


Fig 4-19 Placement of an exploratory curve on a "stiff" stainless steel instrument. The operator slides the instrument down the canal using a "watch winding" motion.

Fig 4-20 Watch-winding motion used to slide the precurved file down the canal.



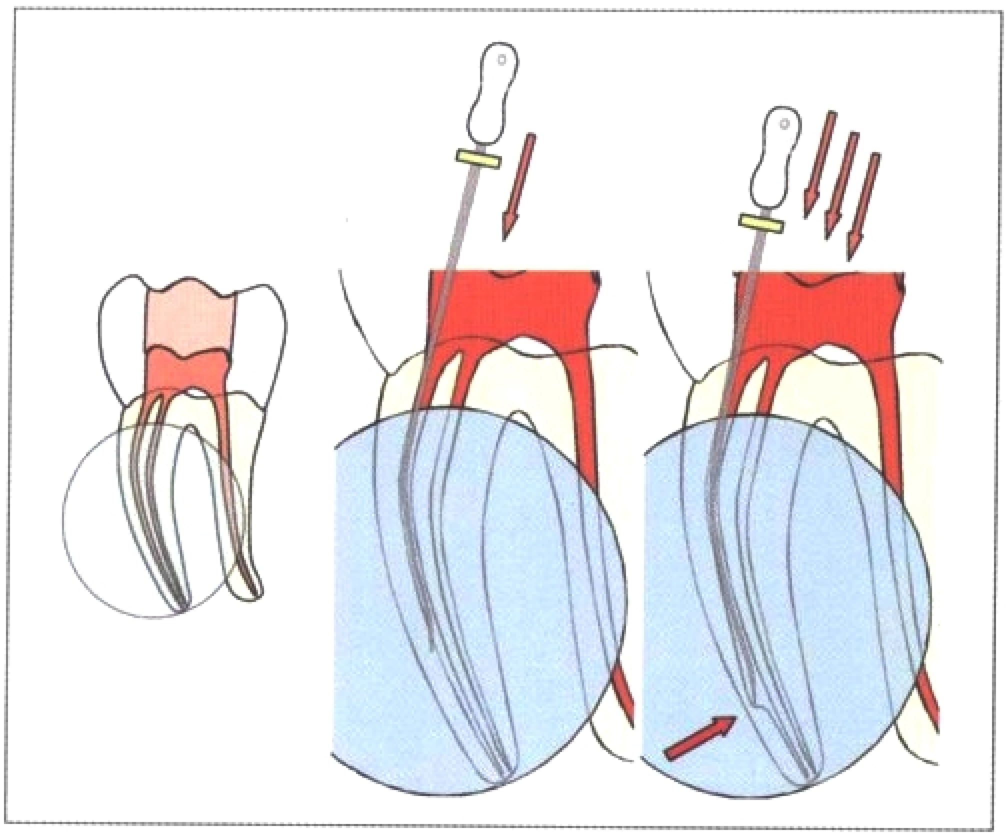


Fig 4-21a Bypassing an obstacle in the canal. If blockage is encountered, it is important not to force the file further into the canal, as this can create a ledge in the canal wall.

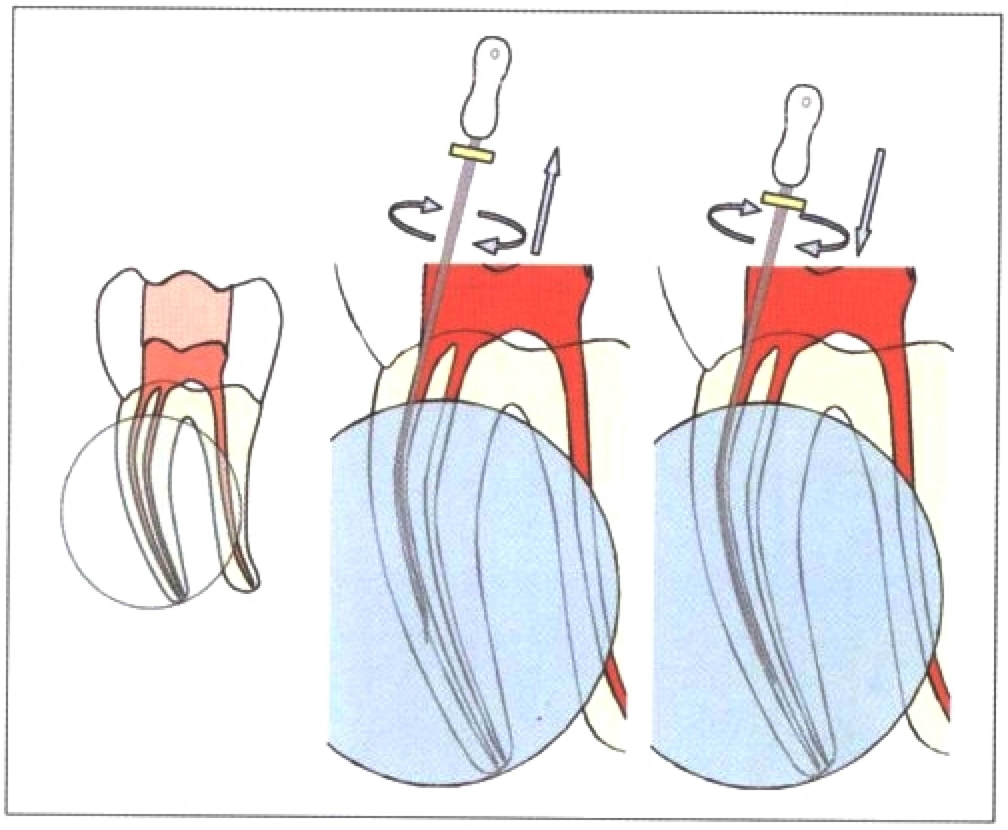


Fig 4-21b Bypassing an obstacle in the canal. The precurved file should be retracted slightly and wound like a watch to change the position of the tip in the canal. An attempt is then made to gently advance the file past the blockage.

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Modified step-back technique with stainless steel files

As stated earlier, the use of an apex-to-crown technique with instruments ranging in size from small to large rarely allows the practitioner to reach a size needed to adequately clean the canal. When this technique is employed, the apical part of the canal becomes packed with dentinal debris that block the larger files' pathway to the apical third or, worse still, direct the file away from a curved canal, causing canal straightening, stripping (perforation in the furca), or even apical perforation. To eliminate these problems, the following modified version of the step-back technique was devised:

1. Using stainless steel files in sizes up to no. 25 (or no. 30 if no. 25 is extremely easy), instrument to the working length. Follow with copious irrigation to rinse the canal.
2. Increase the file by one size to no. 30 (or no. 35) and instrument the canal until the file reaches 1 mm short of the working length. Irrigate as before.
3. Repeat the process until the canal coronal to 4 mm from the working length is instrumented with a size no. 40 file.
4. Using an up-and-down filing motion, increase the size of the canal coronal to 4 mm from the working length (ie, to the same point reached in step 3) using a file one size larger than was used to instrument to the 4-mm point.
5. Re-enter the canal with a size no. 30 file all the way to working length. This instrument should reach the working length easily and with minimal friction as a result of the previous instrumentation.
6. Instrument the apical third of the canal until it reaches a biologically acceptable size (Figs 4-22 and 4-23).

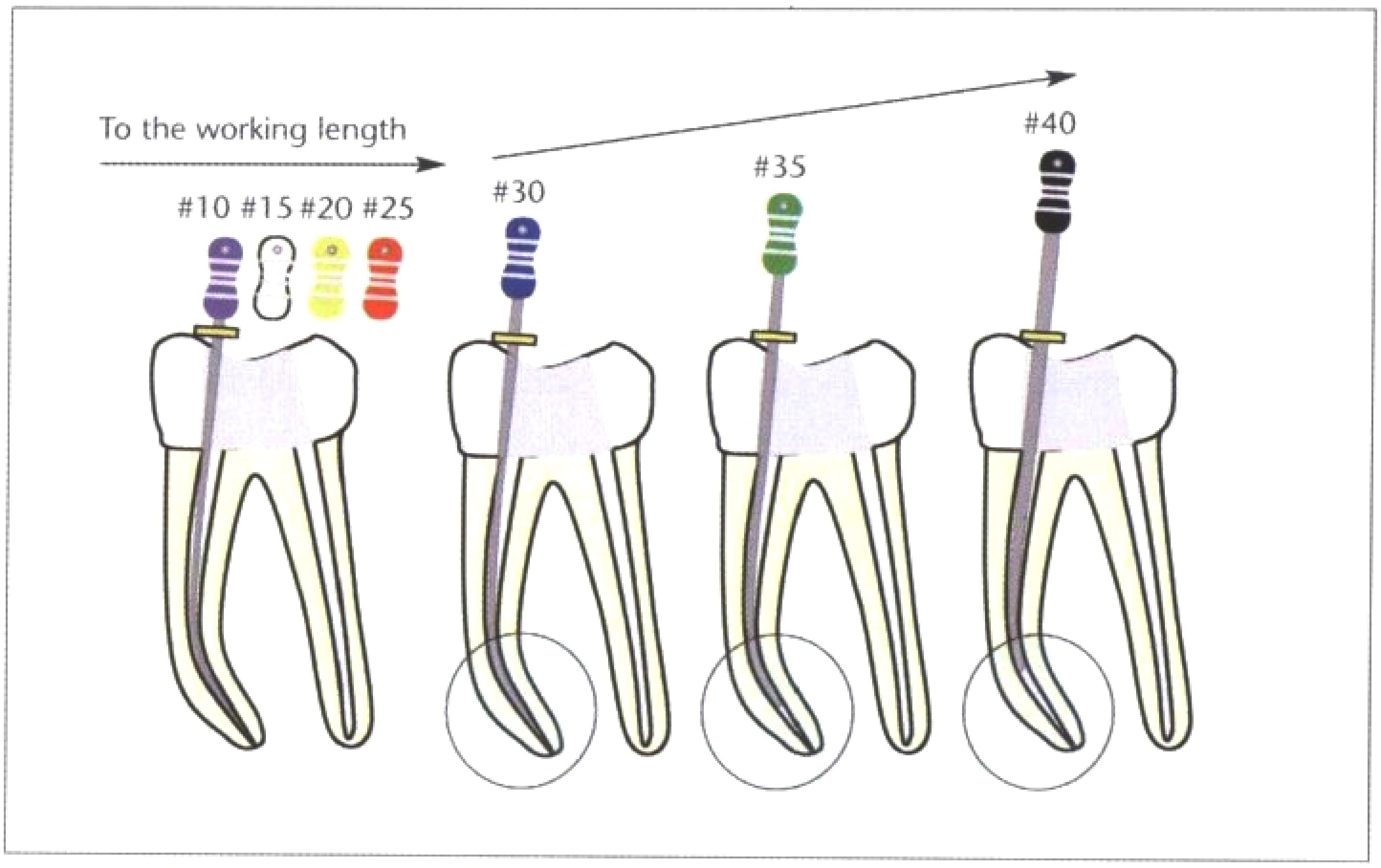


Fig 4-22 Modified step-back technique. Step 1: Space is created in the coronal two thirds of the canal by performing the traditional step-back technique.

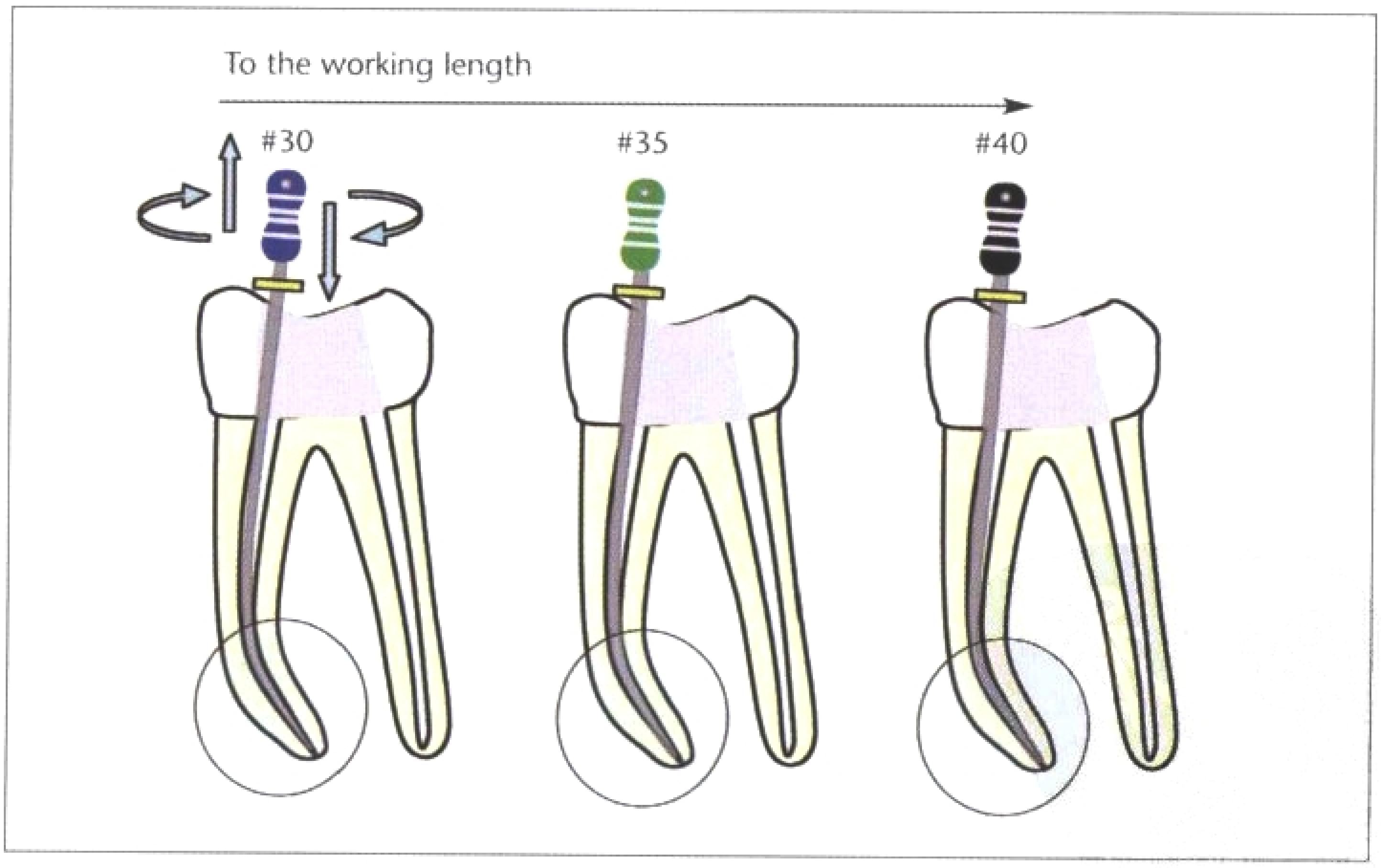


Fig 4-23 Modified step-back technique. Step 2: The apical third of the canal is instrumented to biologic sizes without creating a dentinal plug.

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Crown-down technique with NiTi rotary instruments

As noted above, the authors believe that rotary NiTi instruments offer significant advantages over stainless steel files and should be seriously considered by all practitioners. Indeed, instrumentation of the canal using stainless steel instruments exclusively is a topic that should be discussed only in historic terms. NiTi instruments are extremely flexible and can be bent into almost any position. They will spring back to their original (straight) shape as soon as they are removed from the canal. However, it is important to recognize that, despite their flexibility, there is a tendency for NiTi instruments to straighten the canal. The conflict between the flexibility of the instrument (which allows it to maintain the shape of the canal) and its inherent tendency to straighten (which leads to canal straightening) will ultimately depend on the dentin's resistance to being cut versus the instrument's efficiency in cutting. It is extremely important to know the cutting efficiency of each NiTi file since that will determine how it should be used.

"Nonefficient" cutting instruments

Most of the original NiTi rotary instruments may be classified as "nonefficient" (Fig 4-24). Instead of cutting easily into the dentin, these instruments merely plane the walls of the canal. However, this apparent disadvantage is easily compensated for by the handpiece that powers the instrument at speeds of 150 to 2,000 rpm. It is difficult if not impossible to straighten a canal with one of these instruments, making it ideal for clinicians with no prior experience using NiTi files. The only mishap that can occur is fracturing of the file—there is no danger of straightening the canal.

As a practitioner grows more confident in the use of these files, more aggressive instruments may be considered. Recently, a new type of NiTi instrument was introduced, which features acute-angled cutting edges similar to those found on stainless steel files (Figs 4-25 and 4-26). These acute-angled cutting edges make the instruments much more efficient than their predecessors in the cutting of dentin. The advantage, of course, is that they perform their function much more quickly using fewer instruments than the less-efficient NiTi instruments described above. The drawback of these instruments is their capacity to overcome the resistance of the dentin, thereby increasing the operator's risk of straightening the canal. Recognizing the differences between the two types of NiTi files and knowing which type of file is being used is therefore critically important. Regardless of the type being used, the file must never be left rotating in one position in the canal. While the file is advancing or retreating from the apex, there is little risk of straightening the canal. However, when the file is rotating and allowed to remain stationary within the canal, the result will certainly be a straightened canal.

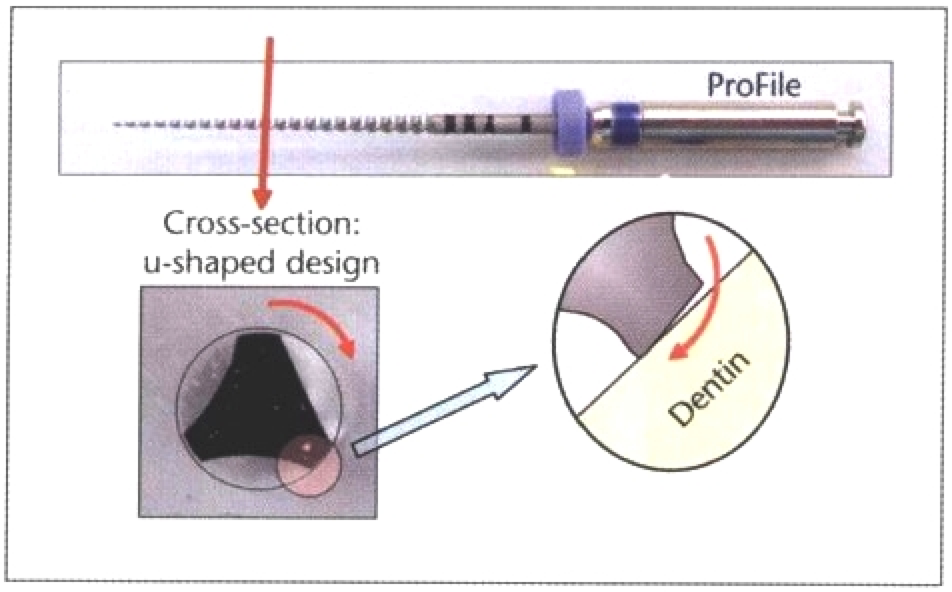


Fig 4-24 ProFile instruments cut inefficiently because of their planing action. This inefficiency guarantees that the canal will not be straightened.

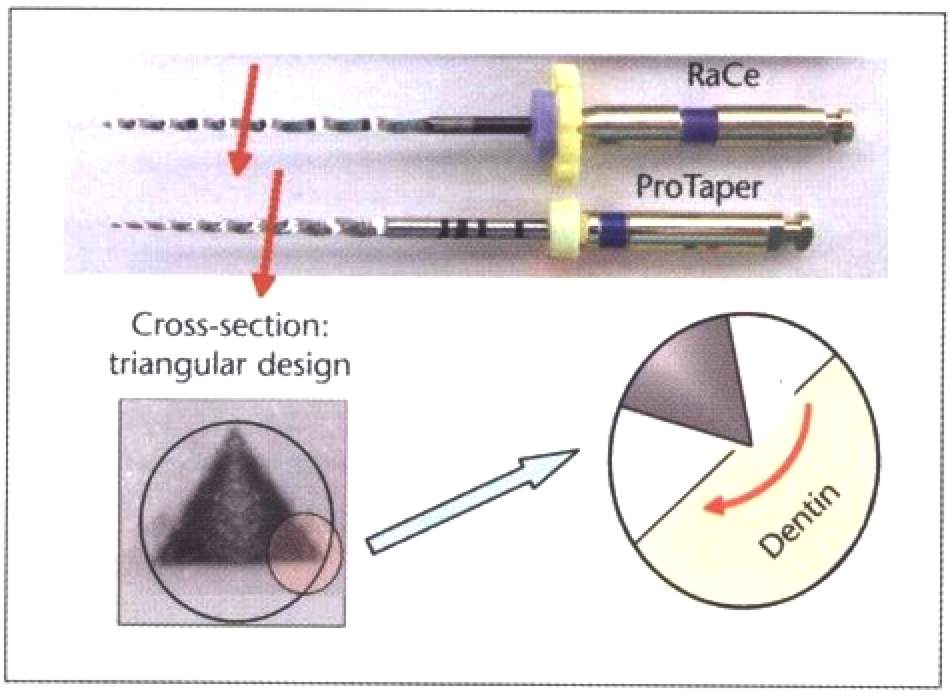


Fig 4-25 ProTaper and RaCe files are efficient cutting instruments because they have acute angles.

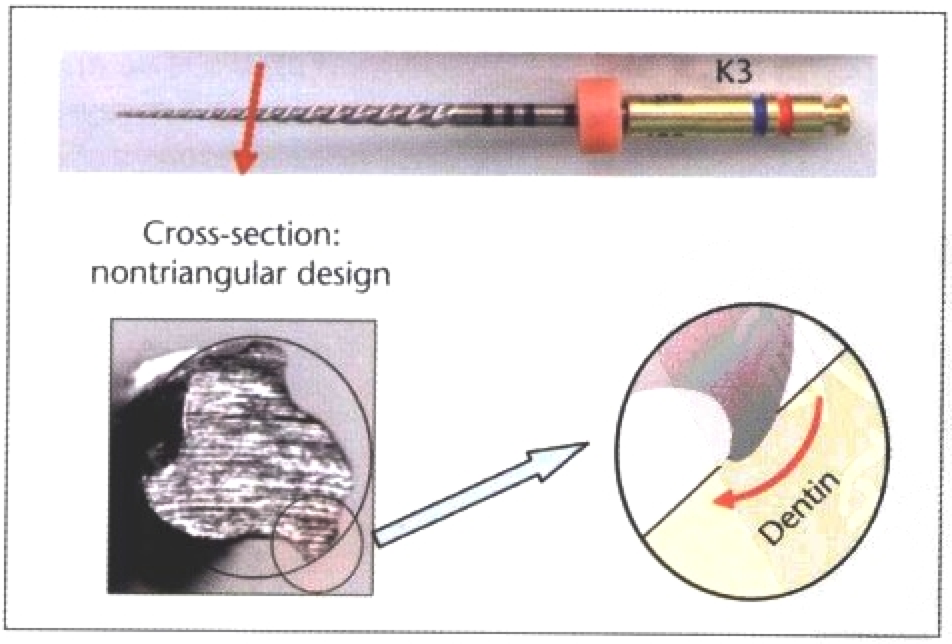


Fig 4-26 K3 also is an efficient cutting file.

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There are many NiTi file systems available on the market today, and all of them, in the authors' opinion, are superior to stainless steel files when used correctly. Below is a list of general guidelines for instrumenting a root canal using NiTi files in two steps: a crown-down technique for the coronal two thirds of the canal, followed by a separate step to enlarge the apical third of the canal.

1. Gain straight-line access to the orifices (see Fig 4-19).
2. Explore the canal using stainless steel exploratory files (see Fig 4-20).
3. Instrument the coronal one third of the canal (ie, working length minus 8 mm) with 0.10 followed by 0.08 and then 0.06 tapered instruments of decreasing tip size (but not less than no. 25) (Fig 4-27).
4. Instrument the middle one third of the canal (ie, working length minus 4 mm) with 0.06 and 0.04 instruments with decreasing tip sizes (but not less than no. 25) (Fig 4-28).

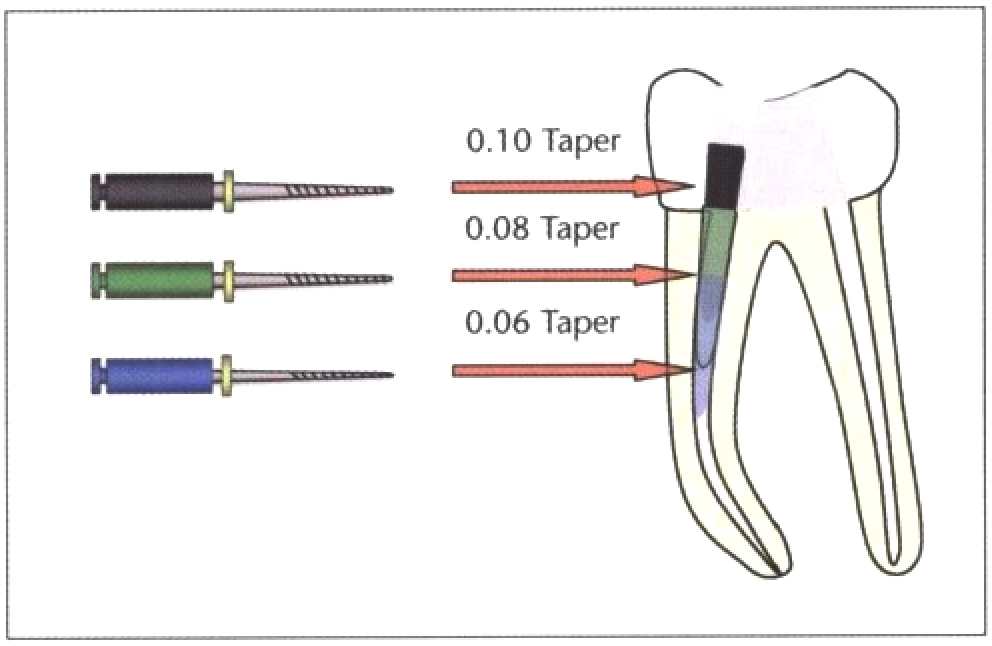


Fig 4-27 Crown-down technique. Preparation of the coronal one third of the canal using files with decreasing taper and, in some systems, decreasing tip sizes.

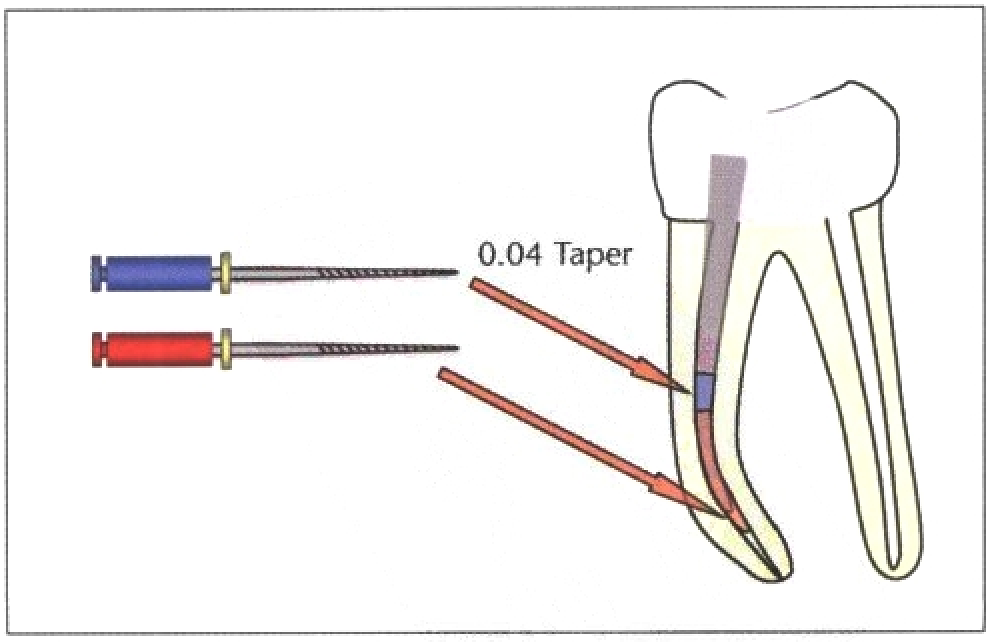


Fig 4-28 Crown-down technique. Continuation of the process with instruments of the same taper but with smaller tip sizes.

Once the coronal two thirds of the canal have been instrumented, determining an accurate working length is imperative since the apical third must be instrumented to the same length with each file. An accurate working length is critical to the success of root canal treatment. For this reason, the authors strongly advise that it be determined only after the coronal two thirds of the canal have been prepared, since this first stage of instrumentation can result in some straightening or shortening of the canal and thereby alter its length.

A number of different methods can be used to determine the correct working length. Using all of them will significantly increase the chances that the instrument length chosen is the correct one.

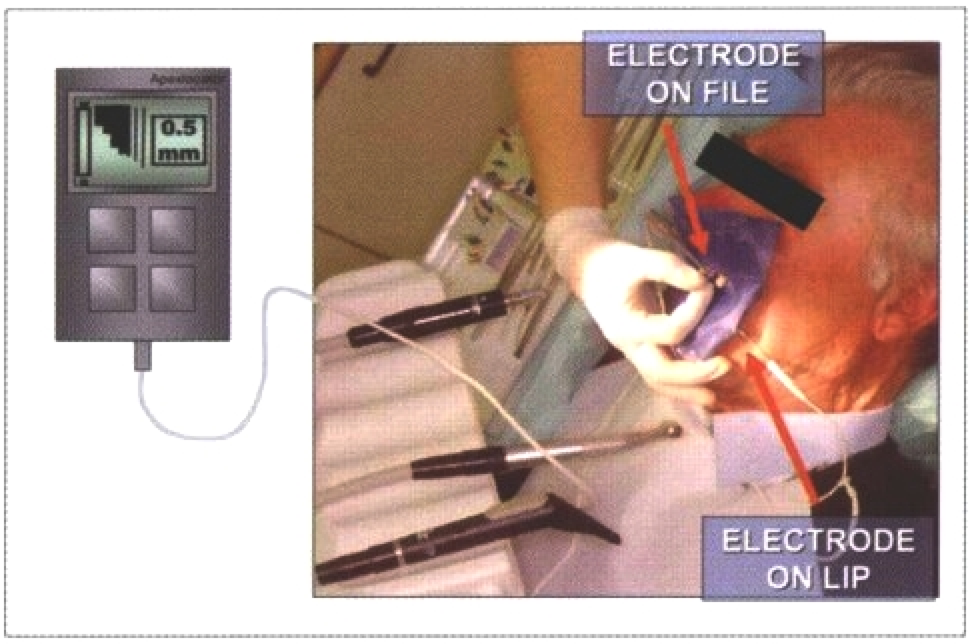


Fig 4-29 The apex locator is one of the most accurate methods available for locating the canal constriction. The electrode is attached to the lip and then the circuit is completed when the second electrode is attached to the file.

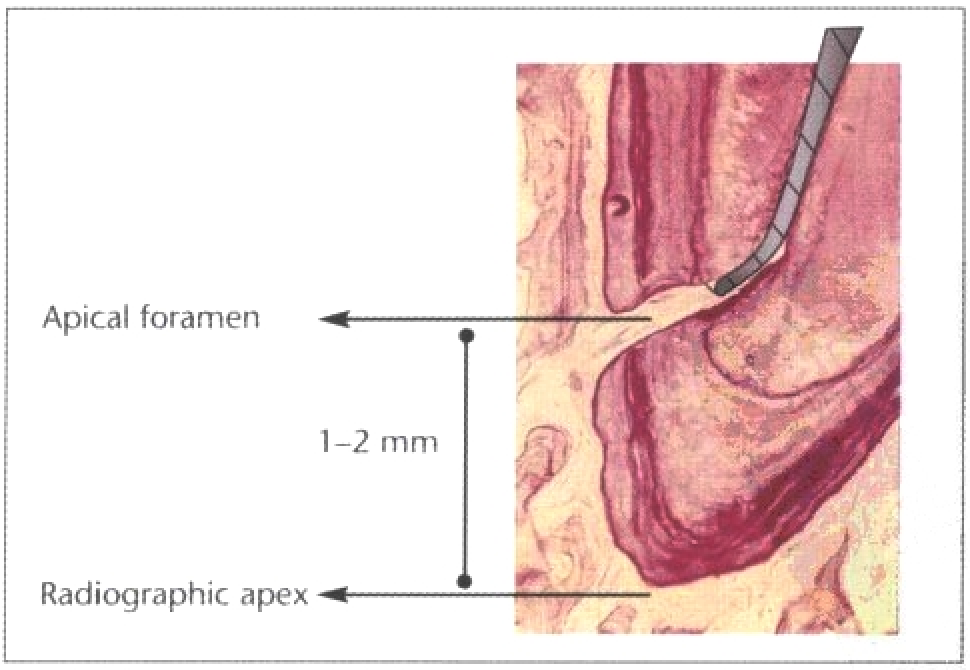


Fig 4-30 The canal constriction is located at a distance that usually falls short of the radiographic apex.

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- Digital feel. Since the coronal two thirds of the canal has already been prepared, it is possible to gauge the size and position of the minor foramen using a small file. A no. 10 file can be placed at the estimated working length; if the file slips past the estimated working length, the file size is too small. Thus, it should be increased until the file hits a "dead stop" close to the estimated working length. Most of the time this dead stop length is the accurate working length.
- Electronic apex locator (Figs 4-29 to 4-31). There are numerous electronic apex locators on the market, most of them accurate and able to work in the presence of some moisture. In the authors' view, this instrument is a valuable tool that should be used in most cases. When following the file's movement toward and away from the minor foramen, this instrument is the most accurate indicator of canal length available.

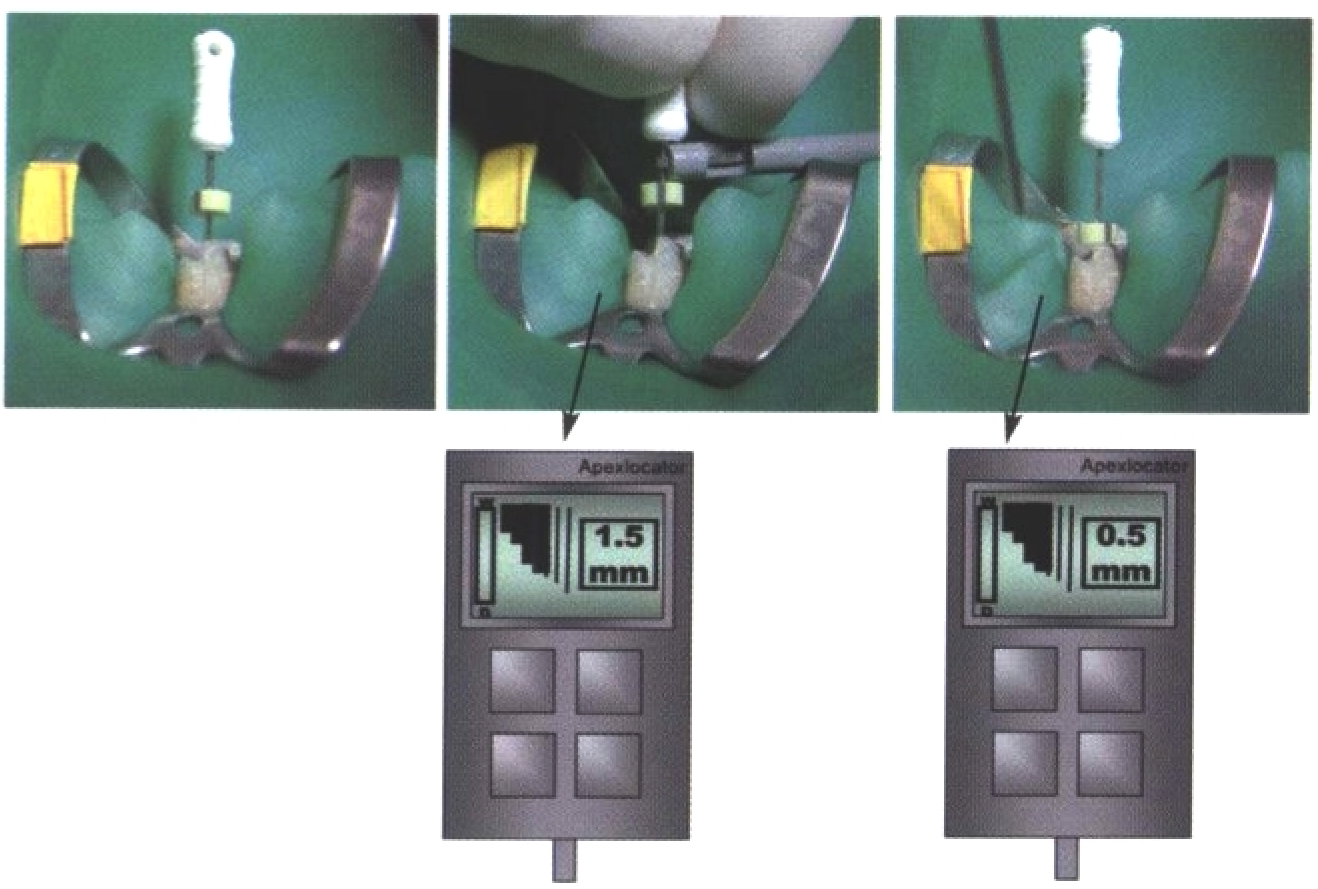


Fig 4-31 The apex locator will start to register a length about 1.5 mm from the apical constriction. In most cases, the length is deemed acceptable when the machine registers 0.5 mm from the apical constriction. If movement of the file between two lengths (1.5 mm and 0.5 mm) registers a corresponding change in the apex locator indicator, the machine is assumed to be accurate.

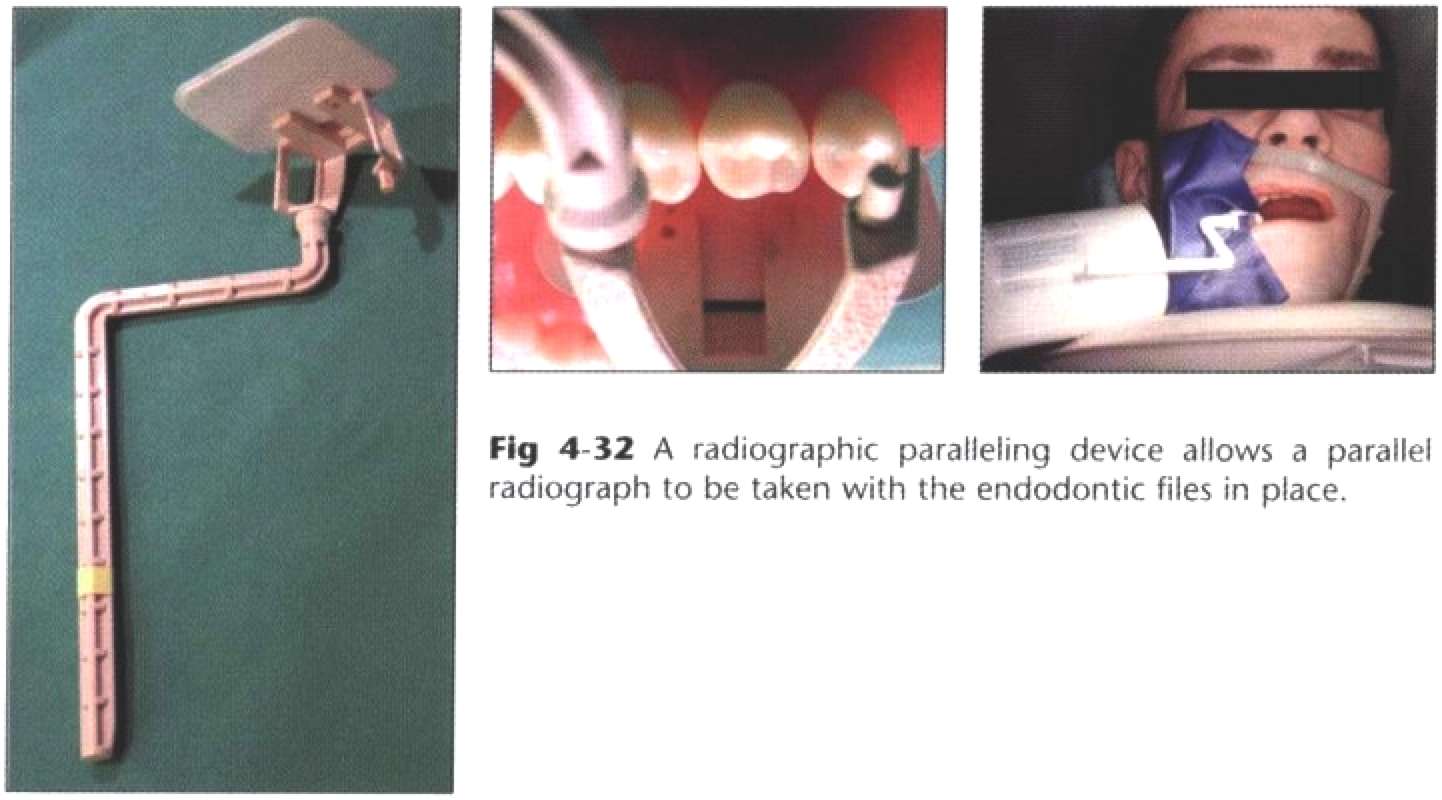


Fig 4-32 A radiographic paralleling device allows a parallel radiograph to be taken with the endodontic files in place.

- Radiograph. A radiograph is the most common means of determining working length. Radiographic paralleling devices (see Estimated Working Length, above) can be used in conjunction with files placed in the tooth (Fig 4-32). However, it is important to recognize that the working length as measured on a radiograph is only an estimate, and therefore digital feel and an apex locator should also be used to confirm the accuracy of the working length.

Once an accurate working length has been determined, rotary NiTi files with ISO sizes 15 to 80 and a taper of 0.02 or 0.04 are used to the appropriate size to maximize the chances of effectively cleaning the canal (Fig 4-33).

- Sizes 15 and over are manually advanced into the canal in progressive succession to identify the instrument that does not reach the accurate working length, usually no. 20 or no. 25.
- The apical third of the canal is then prepared with successively larger sizes until the appropriate size has been reached.

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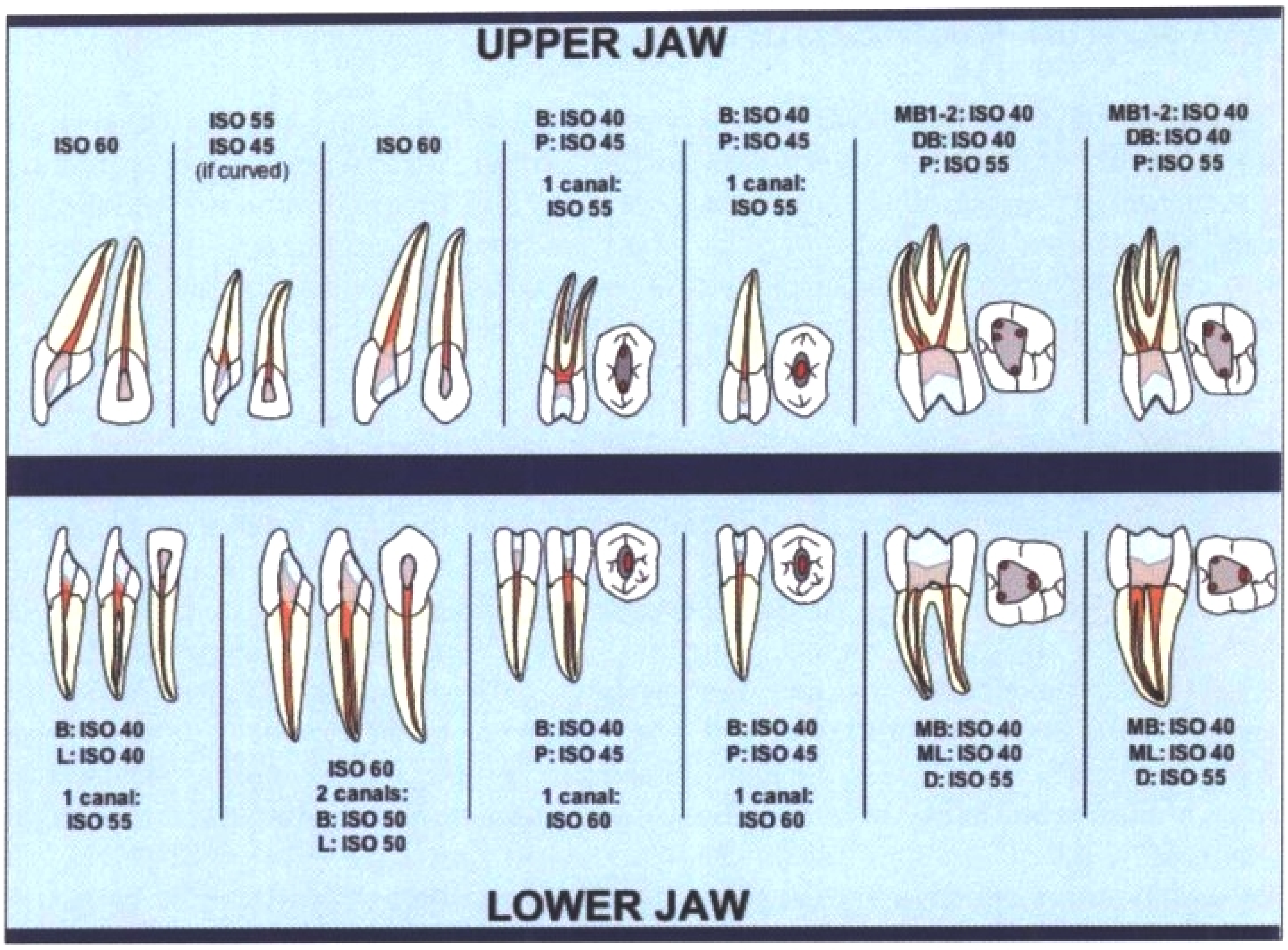
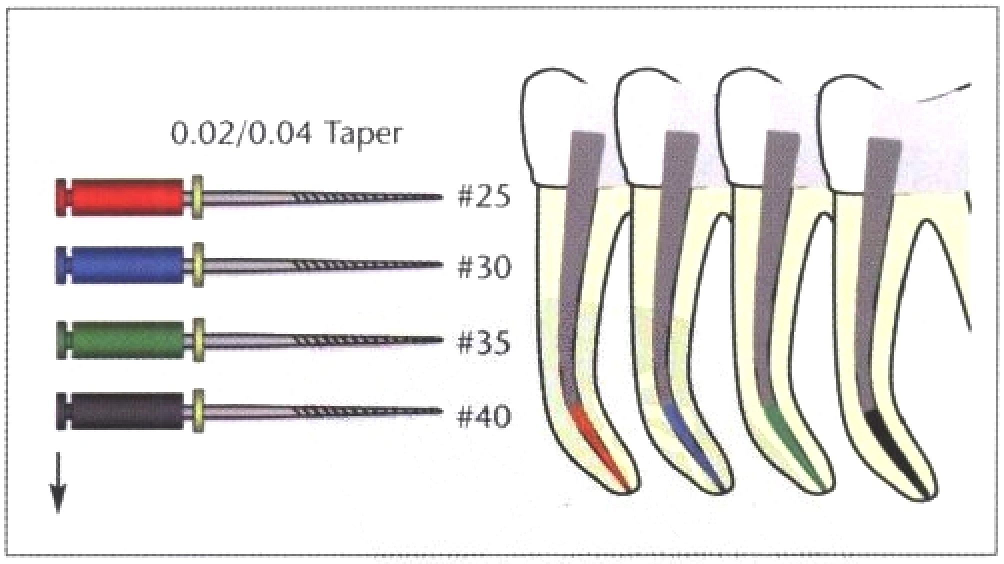


Fig 4-33a Minimum sizes of last apical instrument in root canal instrumentation.

Fig 4-33b Crown-down technique. After the coronal two thirds of the canal has been prepared, the apical one third is prepared to biologic sizes with successively larger files.



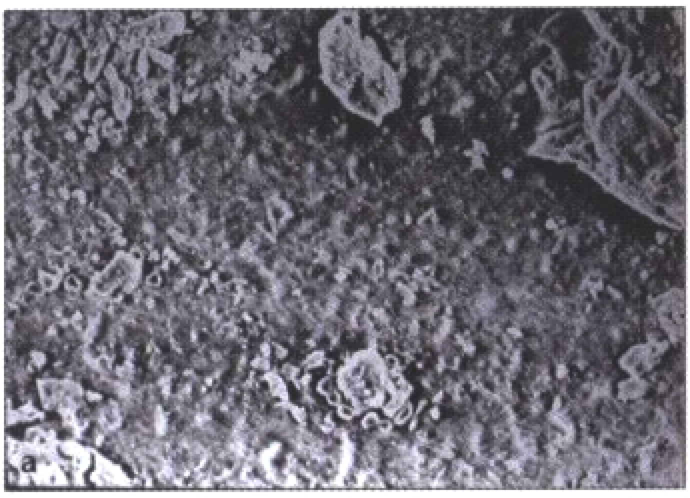
Intracanal Medication

Before the canal is filled, intracanal medication is used to reduce the microbial count and thereby optimize the potential for success. While instrumentation plays the most critical role in the microbial control phase of root canal therapy, intracanal medication is an important adjunct that is necessary for consistent and predictable disinfection of the canals. Intracanal medications can be classified as either irrigating solutions or as medications that remain inside the canal between visits.

Irrigants

Sodium hypochlorite is the most popular intracanal irrigating solution currently in use. It is both antimicrobial and able to break down tissue, which is useful in vital cases. Household bleach is 5.25% sodium hypochlorite, which is considered "full strength" for root canal therapy purposes. Many variations in the use of sodium hypochlorite have been proposed, such as varying the strength (0.5% to 5.25%), the temperature, and the length of time it is left inside the canal. However, none of these factors appears to make a significant difference. Sodium hypochlorite is self-limiting in its antimicrobial action and therefore must be replenished as often as is reasonable. Thus, using a 0.5% solution of sodium hypochlorite that is replenished after every file use will be more effective than heating 5.25% sodium hypochlorite to 60°C (107.6°F) and leaving it in the canal for 30 minutes. Sodium hypochlorite can be used very safely if it "passively" washes the canal. It should never be forced through the apex or into the periapical tissues under pressure. When used in this manner, it is highly toxic and will necrotize the periapical tissues. It is therefore critical that the needle is never wedged into the canal but left loose before the medicament is expressed.

Ethylenediaminetetraacetic acid (17% EDTA) is an effective chelating agent often used in conjunction with sodium hypochlorite to remove the smear layer left behind by instrumentation (Fig 4-34). EDTA itself is not antimicrobial; in removing the smear layer, however, it does effectively eliminate the microorganisms residing there. More-



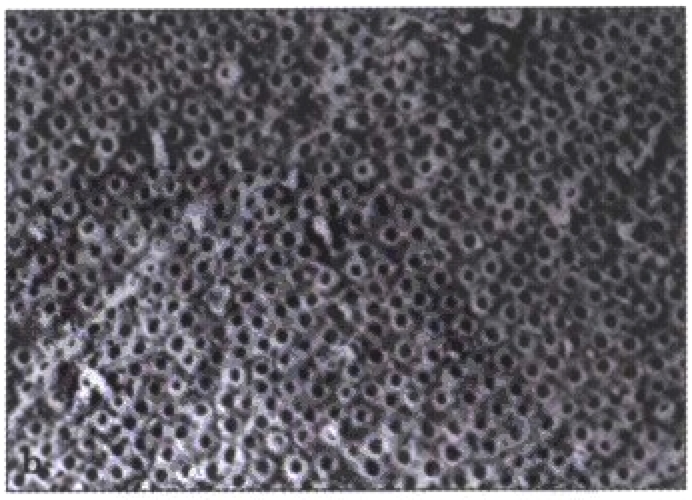


Fig 4-34 Irrigation with sodium hypochlorite alone *(a)* will not remove the smear layer on the canal wall. The addition of 17% EDTA *(b)* is more effective in removing the smear layer, leaving open dentinal tubules.

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over, removal of the smear layer increases the effectiveness of other antimicrobial medicaments within the dentinal tubules. EDTA is applied in the same general manner as sodium hypochlorite, and the two are often used as alternating rinses.

Chlorhexidine (2% chlorhexidine) in water is another effective medicament against root canal microbes. An advantage of this medicament is that it adheres (substantively) to the canal walls, which extends its action for a few days to several weeks. However, it lacks the tissue-dissolving property of sodium hypochlorite. Chlorhexidine also can be use in conjunction with EDTA.

Interappointment medication

Calcium hydroxide ($Ca[OH]_2$) is a medicament used between visits to decrease the microbial count to a level that will guarantee a high rate of success following canal- and crown-filling procedures. $Ca(0H)_2$ should be used routinely in nonvital infected cases and in vital cases when instrumentation and filling cannot be completed within a single visit. $Ca(OH)_2$ powder is mixed with sterile saline or 2% chlorhexidine in water to achieve a creamy toothpaste-like consistency. Using a lentulo-spiral instrument, it is then spun into the prepared canal until it reaches within 2 mm of the working length (Figs 4-35 and 4-36). Commercially prepared soft $Ca(0H)_2$ products are also useful for root canal disinfection.

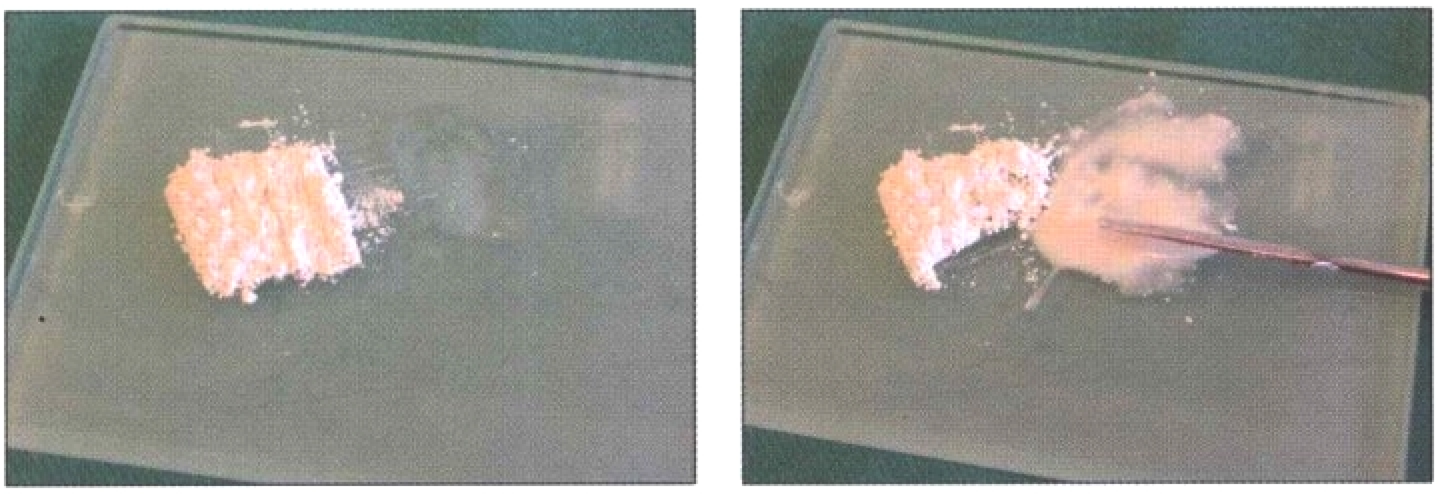


Fig 4-35 Calcium hydroxide powder mixed with saline.

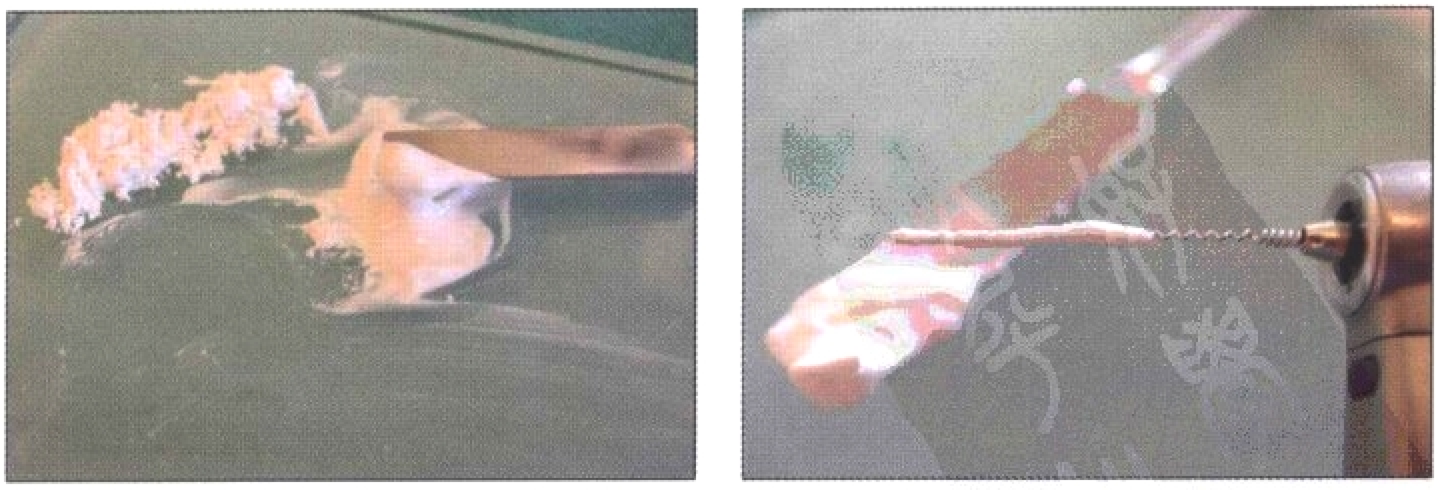


Fig 4-36 The creamy calcium hydroxide is spun into the canal with a lentulo-spiral instrument.

Root Canal Filling

After the microbial control phase is complete, the canal must be filled and sealed. When it is considered appropriate to fill the root canal system, it is also appropriate to place a permanent restoration over it. This coronal restoration is thought to be just as important as the root canal system filling in maintaining an environment that, over time, will result in a healthy periodontium. In creating a hermetic seal in the root canal, the root filling performs three primary functions.

- It entombs remaining microbes in the root canal so that they cannot communicate with the surrounding periodontal ligament to prolong or introduce disease
- It seals out tissue fluids that supply nutrients to the microbes residing in the root canal
- It seals the root canal against microbes communicated via coronal leakage of the saliva.

In addition, the material used to fill the root canals also should have several important properties, including ease of handling, radiopacity, selective toxicity (toxic to microbes in the root canal but not to the periapical tissues when properly applied), and the capacity to be retreated.

Gutta-percha in conjunction with a sealant has been used for many years as the standard root canal filling material. While gutta-percha fulfils most of the secondary functions of a suitable root filling material, it creates a poor seal. Studies have demonstrated conclusively that gutta-percha does not effectively entomb all of the microbes remaining in the canal. In addition, other studies show that gutta-percha and sealant fail miserably in inhibiting coronal leakage. In fact, population studies suggest that the coronal or top filling is critical for periapical health, illustrating the weakness of the gutta-percha filling to seal out oral microbes if the top filling is defective. **Gutta-percha plus sealant represent the weak link in endodontic therapy.**

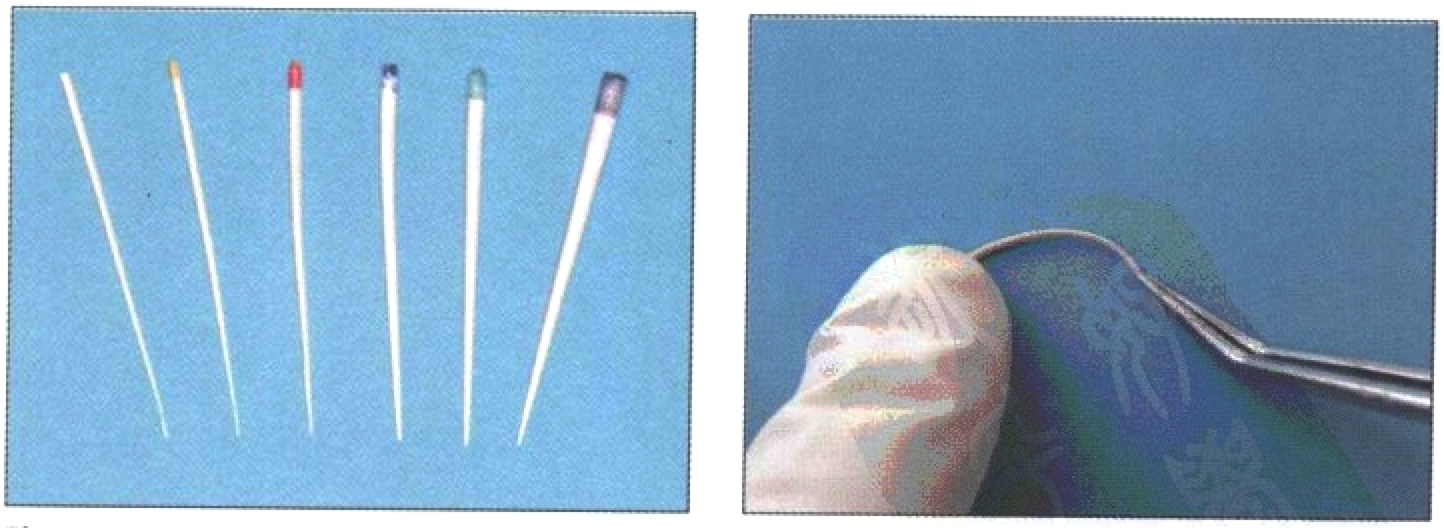


Fig 4-37 Resilon is a modified resin core material that looks and handles like gutta-percha. In addition, fillers have been added to the resin core and sealant that make them retreatable with heat and/or a solvent (Fig 4-38).

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An adhesive root filling system designed to replace gutta-percha was recently developed. The Resilon System consists of a modified resin core material (Fig 4-37) that possesses many of the same properties as gutta-percha (Fig 4-38), including the ability to be thermoplasticized.

Resilon points are dimensionally stable since they consist of fully polymerized and cross-linked resin. When thermoplasticized, the resin maintains its cross-linkages but shrinks upon cooling by 0.5% (compared to gutta-percha's 3% to 7% shrinkage). The root filling is completed with the use of a self-etching primer (Fig 4-39) to remove the smear layer from the canal walls and to wet the root canal surface. The self-etching primer has a low surface tension and is hydrophilic in nature. A dual-curable sealant (see Fig 4-39) is then placed into the canal; this sealant bonds to the canal wall and the resin core material, creating a monoblock that for the first time truly seals the canal (Fig 4-40).

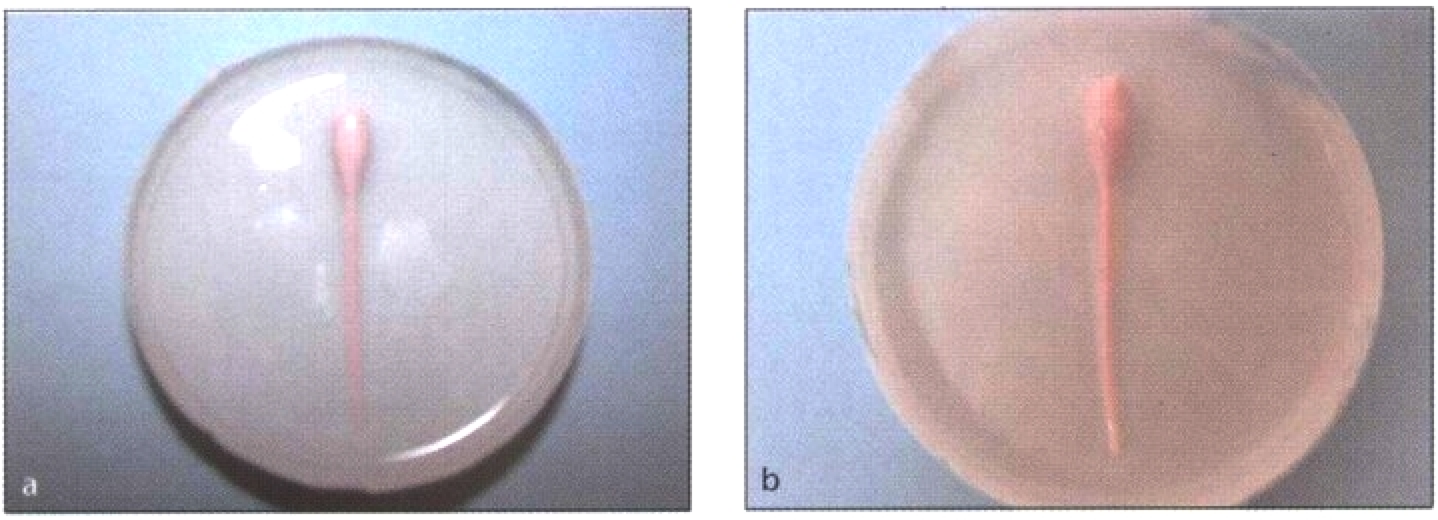


Fig 4-38 If necessary, Resilon can be removed from the root canal with heat and/or solvents. *(a)* Resilon. *(b)* Resilon with chloroform.



Fig 4-39 The self-etching primer will remove the smear layer and wet the root canal surface, thus lowering the surface tension. The dual-cure resin sealant will bind the resin core material to the canal walls, creating a monoblock.

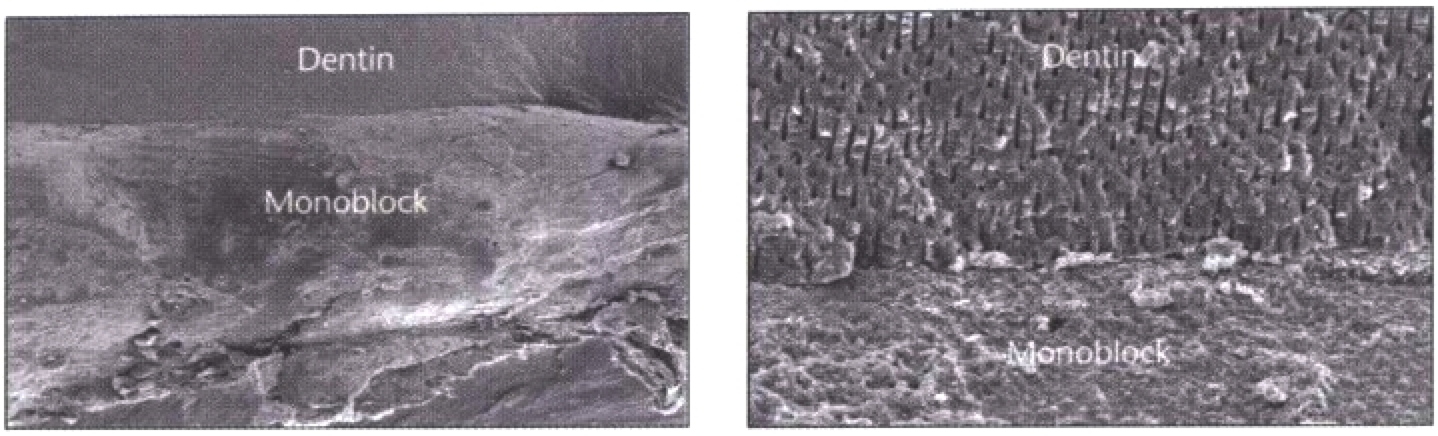


Fig 4-40 Scanning electron micrograph view of the dual-cure resin sealant to the resin core material and to the dentin surface, creating a tight seal against microbial leakage.

Clinical protocol for root canal filling

1. Once the canal has been prepared, EDTA should be used for the final irrigation to remove the smear layer and negate the effect of the NaOCl on the resin bond. Chlorhexidine, which does not affect bond strength, may be added prior to placing the primer (Fig 4-41).
2. Paper points are used to dry the canal, and then an appropriate Resilon master point is placed into the canal. A radiograph is taken to assess whether the Resilon point adapted to the proper apical level. One drop of primer for each canal is dispensed onto a mixing pad. A paper point is soaked in the primer and then placed to length in the canal. Excess primer is dried using additional paper points (Fig 4-42).
3. Next, the sealant is dispensed onto a mixing pad, and, if desired, thinning resin can be added to it to adjust the sealant's viscosity. The Resilon point is coated with sealant, which is then painted on the root canal walls (Fig 4-43).
4. A spreader is used under gentle pressure to create a space between the Resilon point and the canal wall, and an accessory point (FM or MF) covered with sealant is placed into this space. This procedure is repeated until the canal has been filled. A warm stopper is used to sear off the master and accessory points, followed by gentle vertical condensation using a cold stopper (Fig 4-44). Lateral condensation with Resilon generally creates a much lower force than gutta-percha. Although only the lateral condensation technique is described here, all of the thermoplasticized techniques are possible with Resilon. In general, the temperature for adequate flow of Resilon is approximately 30°C lower than for gutta-percha, but each machine should be fine-tuned before use.
5. When root filling is complete, the coronal surface of the root filling may be light-cured for 40 seconds over the pulp chamber, resulting in an immediate coronal seal. Although the resin "monoblock" creates a coronal seal, the final restoration should be placed as soon as possible (Fig 4-45).

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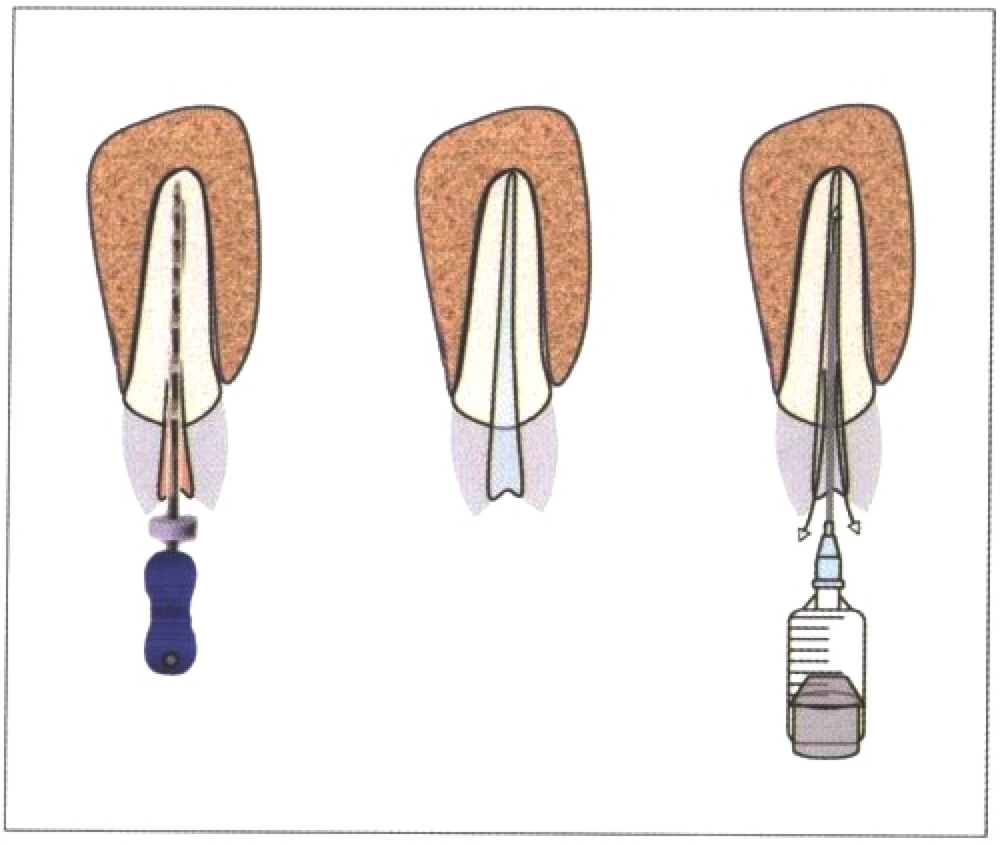


Fig 4-41 The instrumentation is completed with irrigation that may include sodium hypochlorite. For the final irrigation, EDTA and/or 2% chlorhexidine should be used.

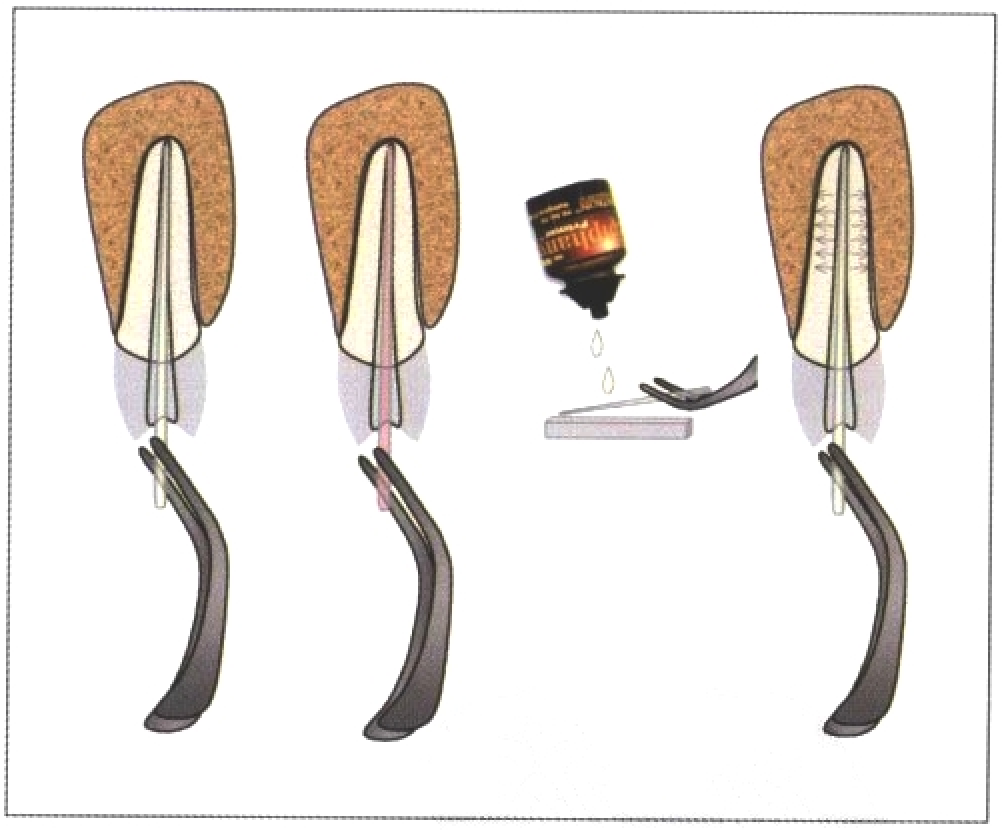


Fig 4-42 The canal is dried with a paper point, the Resilon cone fitted, and a primer-soaked paper point placed to length.

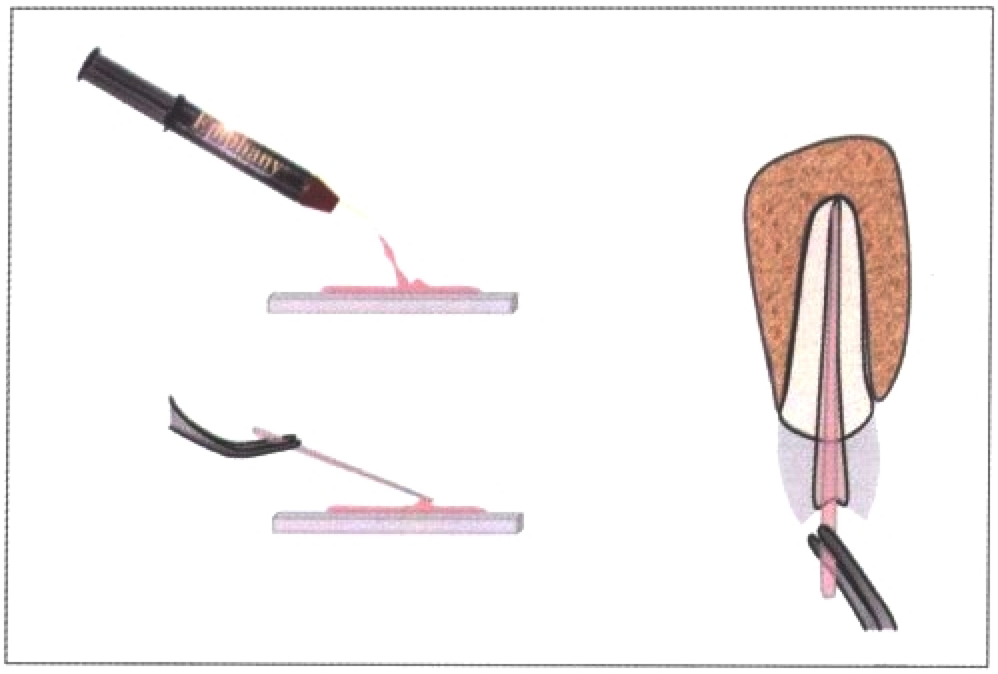


Fig 4-43 The dual-cure sealant is dispensed onto a mixing pad, which is then used to coat the fitted Resilon point. The root canal walls are "painted" with the sealant.

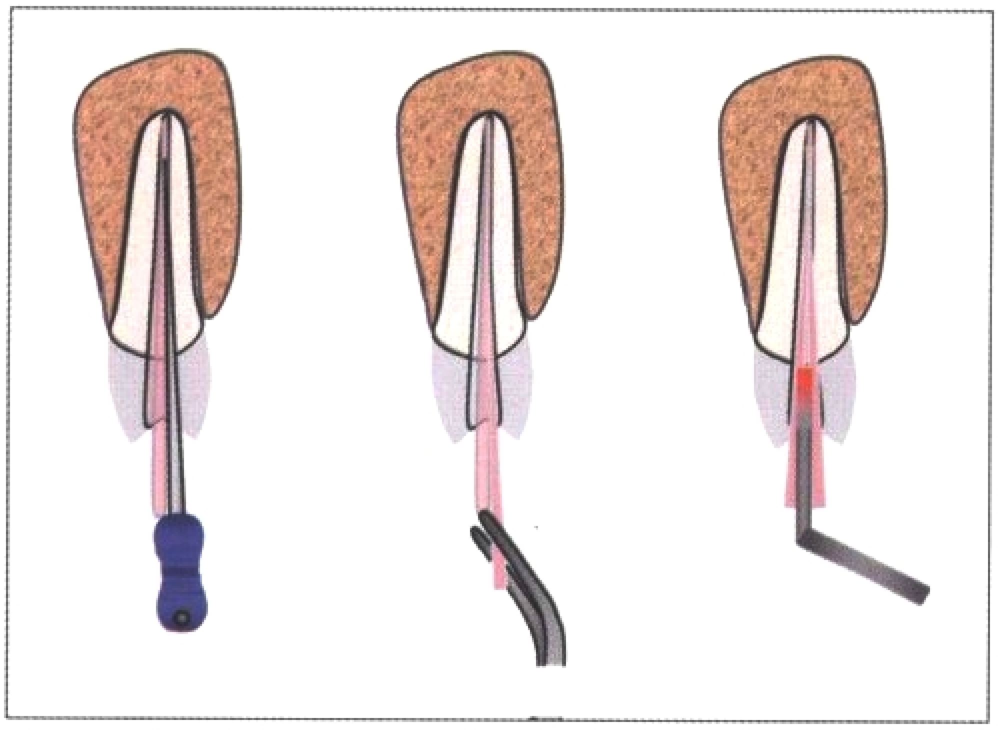


Fig 4-44 Lateral condensation with Resilon. A spreader is used with gentle pressure to explore for space between the master Resilon point and the canal wall. An accessory point covered with sealant is placed into the canal to take up this space. The process is repeated until no more core material can easily be placed into the canal. The excess material is seared off with a hot instrument, and a cold plugger is used to vertically condense the filling material.

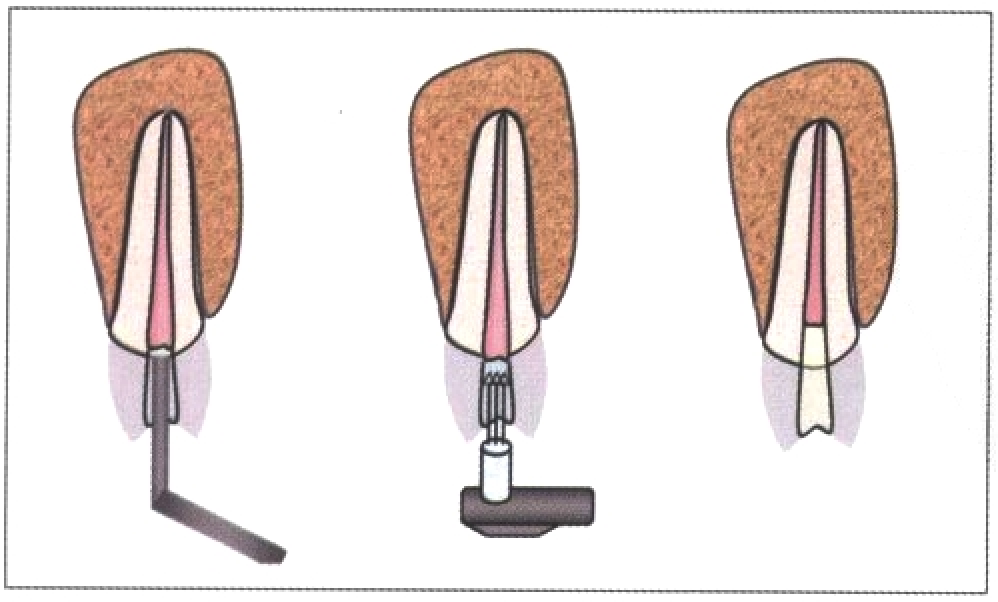


Fig 4-45 After the excess material is removed to the level of the canal orifice, the sealant may be light-cured for 40 seconds to create an immediate coronal seal. The final coronal restoration should be made as soon as possible.

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5 Treatment Outcome and Prognosis of Endodontic Therapy

It goes without saying that a root canal procedure should be attempted only if the clinician is confident of achieving the highest probability of success for that particular tooth. In order to ensure the best possible outcome, it is essential that only cases that can be performed optimally should be started, whereas more complex cases should be referred to a specialist. In addition, the clinician should know the reported success rate of root canal therapy of teeth with various pulpal diagnoses so that an informed choice of treatment plan can be made.

It is difficult to formulate hard and fast rules regarding which cases to attempt and which to refer because every clinician has a different level of competency. In the authors' opinion, new technologies allow dentists to attempt more and more cases that are reasonable. In theory, as long as the canal can be followed with a small stainless steel exploratory file, it should be possible to enlarge and clean the canal with a rotary file system.

The American Association of Endodontists has devised the following Case Difficulty Assessment Forms and Guidelines (printed with permission of the AAE) to help the dentist decide which cases to treat and which to refer to a specialist.

AAE Endodontic Case Difficulty Assessment Form and Guidelines

PATIENT INFORMATION

Name ____________________

Address ____________________

City/State/Zip ____________________

Phone ____________________

DISPOSITION

Treat in Office: Yes No

Refer Patient to: ____________________

Date ____________________

Guidelines for Using the AAE Endodontic Case Difficulty Assessment Form

The AAE designed the Endodontic Case Difficulty Assessment Form for use in endodontic curricula. The Assessment Form makes case selection more efficient, more consistent and easier to document. Dentists may also choose to use the Assessment Form to help with referral decision making and record keeping.

Conditions listed in this form should be considered potential risk factors that may complicate treatment and adversely affect the outcome. Levels of difficulty are sets of conditions that may not be controllable by the dentist. Risk factors can influence the ability to provide care at a consistently predictable level and impact the appropriate provision of care and quality assurance.

The Assessment Form enables a practitioner to assign a level of difficulty to a particular case.

LEVELS OF DIFFICULTY

MINIMAL DIFFICULTY	Preoperative condition indicates routine complexity (uncomplicated). These types of cases would exhibit only those factors listed in the MINIMAL DIFFICULTY category. Achieving a predictable treatment outcome should be attainable by a competent practitioner with limited experience.
MODERATE DIFFICULTY	Preoperative condition is complicated, exhibiting one or more patient or treatment factors listed in the MODERATE DIFFICULTY category. Achieving a predictable treatment outcome will be challenging for a competent, experienced practitioner.
HIGH DIFFICULTY	Preoperative condition is exceptionally complicated, exhibiting several factors listed in the MODERATE DIFFICULTY category or at least one in the HIGH DIFFICULTY category. Achieving a predictable treatment outcome will be challenging for even the most experienced practitioner with an extensive history of favorable outcomes.

Review your assessment of each case to determine the level of difficulty. If the level of difficulty exceeds your experience and comfort, you might consider referral to an endodontist.

The AAE Endodontic Case Difficulty Assessment Form is designed to aid the practitioner in determining appropriate case disposition. The American Association of Endodontists neither expressly nor implicitly warrants any positive results associated with the use of this form. This form may be reproduced but may not be amended or altered in any way.

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AAE Endodontic Case Difficulty Assessment Form

Criteria and Subcriteria	Minimal Difficulty	Moderate Difficulty	High Difficulty
A. PATIENT CONSIDERATIONS			
Medical history	☐ No medical problem (ASA Class 1*)	☐ One or more medical problems (ASA Class 2*)	☐ Complex medical history/serious illness/disability (ASA Classes 3-5*)
Anesthesia	☐ No history of anesthesia problems	☐ Vasoconstrictor intolerance	☐ Difficulty achieving anesthesia
Patient disposition	☐ Cooperative and compliant	☐ Anxious but cooperative	☐ Uncooperative
Ability to open mouth	☐ No limitation	☐ Slight limitation in opening	☐ Significant limitation in opening
Gag reflex	☐ None	☐ Gags occasionally with radiographs/treatment	☐ Extreme gag reflex which has compromised past dental care
Emergency condition	☐ Minimum pain or swelling	☐ Moderate pain or swelling	☐ Severe pain or swelling
B. DIAGNOSTIC AND TREATMENT CONSIDERATIONS			
Diagnosis	☐ Signs and symptoms consistent with recognized pulpal and periapical conditions	☐ Extensive differential diagnosis of usual signs and symptoms required	☐ Confusing and complex signs and symptoms: difficult diagnosis ☐ History of chronic oral/facial pain
Radiographic difficulties	☐ Minimal difficulty obtaining/interpreting radiographs	☐ Moderate difficulty obtaining/interpreting radiographs (e.g., high floor of mouth, narrow or low palatal vault, presence of tori)	☐ Extreme difficulty obtaining/interpreting radiographs (e.g., superimposed anatomical structures)
Position in the arch	☐ Anterior/premolar ☐ Slight inclination (<10°) ☐ Slight rotation (<10°)	☐ 1st molar ☐ Moderate inclination (10-30°) ☐ Moderate rotation (10-30°)	☐ 2nd or 3rd molar ☐ Extreme inclination (>30°) ☐ Extreme rotation (>30°)
Tooth isolation	☐ Routine rubber dam placement	☐ Simple pretreatment modification required for rubber dam isolation	☐ Extensive pretreatment modification required for rubber dam isolation
Morphologic aberrations of crown	☐ Normal original crown morphology	☐ Full coverage restoration ☐ Porcelain restoration ☐ Bridge abutment ☐ Moderate deviation from normal tooth/root form (e.g., taurodontism, microdens) ☐ Teeth with extensive coronal destruction	☐ Restoration does not reflect original anatomy/alignment ☐ Significant deviation from normal tooth/root form (e.g., fusion, dens in dente)
Canal and root morphology	☐ Slight or no curvature (<10°) ☐ Closed apex (<1 mm in diameter)	☐ Moderate curvature (10-30°) ☐ Crown axis differs moderately from root axis. Apical opening 1-1.5 mm in diameter	☐ Extreme curvature (>30°) or S-shaped curve ☐ Mandibular premolar or anterior with 2 roots ☐ Maxillary premolar with 3 roots ☐ Canal divides in the middle or apical third ☐ Very long tooth (>25 mm) ☐ Open apex (>1.5 mm in diameter)
Radiographic appearance of canal(s)	☐ Canal(s) visible and not reduced in size	☐ Canal(s) and chamber visible but reduced in size ☐ Pulp stones	☐ Indistinct canal path ☐ Canal(s) not visible
Resorption	☐ No resorption evident	☐ Minimal apical resorption	☐ Extensive apical resorption ☐ Internal resorption ☐ External resorption
C. ADDITIONAL CONSIDERATIONS			
Trauma history	☐ Uncomplicated crown fracture of mature or immature teeth	☐ Complicated crown fracture of mature teeth ☐ Subluxation	☐ Complicated crown fracture of immature teeth ☐ Horizontal root fracture ☐ Alveolar fracture ☐ Intrusive, extrusive or lateral luxation ☐ Avulsion
Endodontic treatment history	☐ No previous treatment	☐ Previous access without complications	☐ Previous access with complications (e.g., perforation, non-negotiated canal, ledge, separated instrument) ☐ Previous surgical or nonsurgical endodontic treatment completed
Periodontal-endodontic condition	☐ None or mild periodontal disease	☐ Concurrent moderate periodontal disease	☐ Concurrent severe periodontal disease ☐ Cracked teeth with periodontal complications ☐ Combined endodontic/periodontic lesion ☐ Root amputation prior to endodontic treatment

*American Society of Anesthesiologists (ASA) Classification System

Class 1 No systemic illness. Patient healthy.
Class 2 Patient with mild degree of systemic illness, but without functional restrictions, e.g., well-controlled hypertension
Class 3 Patient with severe degree of systemic illness which limits activities, but does not immobilize the patient
Class 4 Patient with severe systemic illness that immobilizes and is sometimes life threatening
Class 5 Patient will not survive more than 24 hours whether or not surgical intervention takes place

www.asahq.org/clinical/physicalstatus.htm

University-based studies on endodontic outcome have shown overall success rates to be around 90%. However, cross-sectional, retrospective population studies have revealed success rates in only 60% to 75% of cases. It has been shown that there is a consistent association in the cross-sectional studies between poor quality of the root fillings and the presence of a periapical radiolucency. However, several epidemiologic studies have demonstrated that many pretreatment, intratreatment, and post-treatment factors may influence the prognosis of root canal treatment.

Factors Affecting the Prognosis of Endodontic Therapy

Pretreatment factors

Pretreatment factors presented in the literature that may influence the prognosis of endodontic therapy include: age, gender, general health, tooth location, pulp status, symptoms, size of the lesion, and periodontal conditions. However, only the presence of apical periodontitis has been demonstrated to influence the treatment outcome, leading to a 10% to 25% lower success rate than if it were not present preoperatively. Poorer treatment outcome in teeth with apical periodontitis highlights the difference between prevention (which is a challenge of asepsis) and treatment (which is a challenge of disinfection) of an established disease. Poorer outcome may also reflect a lack of understanding as to the importance of disinfection of the root canal before it is filled. We are confident that the prognosis of teeth with and without pretreatment apical periodontitis will be equally high if the suggested protocol described in this manual is followed.

In retreatment cases, pretreatment apical periodontitis is clearly demonstrated to be even more detrimental to the treatment outcome, thereby highlighting the difficulty in disinfecting the root canals of previously treated teeth.

Treatment-related factors

Several treatment-related factors may influence the prognosis of endodontic treatment, including apical extent of root canal filling, apical enlargement, number of treatment sessions, materials and techniques used, and treatment complications. Extrusion of filling materials beyond the root end generally results in a poorer treatment outcome in cases with periapical inflammation, but it does not compromise teeth with a healthy apical periodontium. It is observed that in infected canals, a root filling that is shorter than 1 mm from the radiographic apex results in a less favorable prognosis than one that is filled 0.5 to 1 mm from the radiographic apex. In noninfected cases, root canal fillings 0 to 2 mm from the radiographic apex have similarly high outcomes. Also, the use of a calcium hydroxide intracanal medicament in teeth with apical periodontitis appears to result in a higher incidence of healing. Some studies have demonstrated a higher success rate (about 9%) for treatments using the

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Treatment Outcome and Prognosis of Endodontic Therapy

- Vital and necrotic pulps without periapical lesions: 90–98%
- Nonvital pulps with periapical lesions: 80–90%, drop to 50–60% with bad endodontic quality
- Retreatment of teeth without periapical lesions: 89–96%
- Retreatment of teeth with periapical lesions: 60–74%

Fig 5-1

modified step-back technique. Moreover, it appears that different sealants may influence the prognosis of the treatment. Treatment complications, such as perforations in the furcation area, file separations, and sealant extrusion, may contribute to a surprisingly small proportion (4%) of endodontic treatment failures.

Post-treatment factors

It has become increasingly clear that coronal microleakage following endodontic therapy may lead to root canal infection and subsequent failure. The coronal restoration will protect the root canal filling material and provide an additional barrier to reinfection of the root canal space. In cases where the canal is filled with gutta-percha and sealant, the coronal restoration may be more effective (and thus more important) than the root filling in preventing coronal microleakage.

During the past 80 years, numerous studies have been published on the prognosis and treatment outcome of endodontic therapy. Most of these studies vary considerably in material composition, treatment procedures, and methodology, which makes it difficult to compare them and form solid conclusions. Nevertheless, the information accumulated from these studies provides insight into the outcome of endodontic therapy (Fig 5-1). The following general conclusions can be made:

- The prognosis of endodontic therapy, when performed optimally, is extremely good.
- Reasons for failure of endodontic treatment are almost always infection in the root canal space and its influence on the periapical tissues.
- Endodontic infection is often associated with inadequate root canal instrumentation and root canal filling, and/or inadequate coronal restoration.

Treatment Follow-up

Failures following endodontic therapy do occur. Thus, clinical-radiographic follow-up examinations should take place 6 and 12 months after completion of the treatment. If necessary, the period of observation can be extended up to 4 years, especially in cases of apical periodontitis.

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